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# SCIENTIFIC AMERICAN SUPPLEMENT

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**As first formed, a hat is rough, shapeless and flimsy**

**MAKING HATS FOR OUR DOUGHBOYS** **[See page 360]**

# The Relation of the Weather to Agriculture*

## Increased Production from a Better Climatic Distribution of Cultivated Species

THE problems involved in Agricultural Meteorology are of the highest importance with regard to the maximum yield of crops in any given locality. In 1911 the International Institute of Agriculture at Rome formed an International Meteorological Committee for the purpose of studying this question. In 1912 this Committee delegated to a Commission of five members the task of elaborating a plan of international organization of agricultural meteorology. The outbreak of the war unfortunately interrupted this admirable project. This vitally important problem, however, has been widely studied by various scientists, and quite recently an Italian savant, Mr. G. Azzi, has published a series of monographs[1] setting forth the results of his investigation of the problems involved. So important are these considered that the International Institute of Agriculture has made them the subject of a special report, an abstract of which here follows:

### I. THE ELEMENTS OF THE PROBLEM.

Among the variations which exist in the yield of crops those due to atmospheric vicissitudes come first, being far more important, for example, than those due to a difference of fertilizers, or of labor methods etc. Hence those studies which have for their object the lessening of the damage caused by unfavorable weather merit the greatest attention. Three factors must be taken into consideration in the endeavor to solve the problems of agricultural meteorology: 1. The knowledge of the critical period; 2. Phenological charts; 3. Weather maps.

1. *The Critical Period.* During the period between the time of germination and the harvest the plant undergoes profound modifications which alter both its form and its structure, so that its requirements with respect to the various meteorological factors necessarily vary during the course of the vegetative period.

The critical period with respect to "rainfall" is the longer or shorter interval of the vegetative period, during which the plant has an absolute need of a certain minimum quantity of atmospheric precipitations.

If the sum total of these precipitations during the critical period is less than the minimum compatible with the normal development of the plant the harvest will be small, even if there has been abundant rain during the rest of the vegetative period; and inversely, if the requirements of the plant are satisfied during the critical period the harvest will be abundant, even if the rainfall during the rest of the vegetative period is scanty and badly distributed. The critical period for cereals falls within the twenty days preceding the formation of the ear: if at this time the rainfall is not sufficient to maintain the humidity of the soil above a certain limit the crop will be seriously compromised.

The same thing is true for the other meteorological factors concerned; hence a plant may have a critical period with regard not only to rainfall but to frost, to temperature, to clouds, etc. One or the other of these periods, or all of them, according to the local conditions of the climate, may assume or acquire importance. The necessity of a careful and detailed physiologic and meteorological examination is therefore evident, if it be desired to determine with precision in any given locality the causes of a poor harvest and the proper remedies therefor.

2. *Phenological Charts.*—Phenology is the science which deals with the relation between climate and various periodical phenomena, such as the flowering of plants, the maturing of crops, the migration of birds, etc. The average period of the blossoming of the peach tree, for example, at various stations distributed throughout Italy, has been calculated, and the data relating to this subject are shown upon a map of the peninsula at the points corresponding to the various stations. All those points at which the blossoming occurs in the same ten-day period are comprised in a single zone and the various zones are tinted in different colors: We thus obtain the phenological chart of the blossoming of the peach.

The critical period referred to above always coincides with some special phase of the vegetation (flowering, earing, etc.), i. e., with one of those times during which the plant undergoes profound modifications which render it for the moment very exacting, for example, with respect to humidity, or very sensitive to the action of unfavorable weather conditions. Thus, during the phase of the flowering of fruit trees a fall of temperature, which during other portions of the vegetative period would have no effect, may seriously injure the fruit crop.

If we know the average date of the various phases in the development of the plant (budding, flowering, setting of the fruit, maturing of the fruit), we can determine those epochs of the year when the plant is peculiarly sensitive to the harmful action of certain phenomena, or particularly exacting with respect to humidity, temperature, etc. Thus, for example, if the flowering of the peach takes place at station A about the 5th of February, on the average, we say that in that locality the critical period of the peach with respect to frost begins during the first ten days of February. Hence, phenological charts enable us to fix the date of the critical period. We will then have as many phenological charts for each cultivated species as there are phases of vegetation which are of importance with respect to the weather; thus, in the case of cereals we shall have: 1, germination; 2, earing; 3, flowering; 4, maturing of the caryopses.

3. *Weather Maps.*—In 1910, in the Province of Bologna, during the twenty days previous to the earing, which occurred May 15th, there was no rainfall, and the harvest was much lower than the average, with a yield of 12 quintals to the hectar. Abundant rain fell, on the contrary, during the first half of the month of April. By advancing the time of sowing, or by planting an earlier variety, it would have been possible to change the phase of the formation of the ear to the period between the 25th and the 30th of April, so a sto make the critical period with relation to humidity coincide with a more favorable period with respect to the weather but for such an operation it would be necessary to know as early as the end of October what sort of weather we shall have in spring. Unfortunately, a good forecast of the weather is never more than twenty-four hours or at the maximum forty-eight hours beforehand: *It is not possible, therefore, to adapt the crops to the weather.*

However, if we are not capable of foretelling in the autumn what will be the atmospheric vicissitudes at Bologna and at Sciacca (Sicily) during the second half of April, yet one thing is always quite certain: i. e., that drought during this last period is far more probable and frequent at Sciacca than at Bologna.

*Though we may not be able to adapt the crops to the weather, it is, however, possible to adapt them to the climate, which is the average weather,* and this is expressed by a series of percentages of probability: the probability of frost, of drought, of storms, of clouds, etc.

We may term the "dry decade" a period of ten days in which the total precipitation does not exceed 5 mm. By calculating for a certain number of localities, and for a long period of time( not less than twenty years), the number of times in which a certain "decade" has been "dry" we can obtain a percentage which will indicate the probability of drought for the said "decade." Let us suppose that at station A the second "decade" of July had been dry fifteen times in twenty years: this would indicate that the probability of drought in the second "decade" of July at station A was 75%. This percentage is marked on a geographic map at the points corresponding to the different stations and places of observation. All those points where the probability of drought is from 70 to 100% will form a single zone—the zone in which drought is nearly certain to occur; the points where this probability is from 30 to 70% will form a second zone; finally those where it is from zero to 30% will form a third zone in which drought is very rare in the given decade. The various zones are colored blue, violet, pink, etc.

We shall thus obtain for each "decade" a map enabling us to form at a glance of the eye an idea as to the distribution of drought in the "decade" in question. Frost maps, i. e., maps showing a cold "decade" period of ten days during which frost occurred can be made in a similar manner, and also those indicating similar periods of cloudy weather, of storms and of fog.

### II. STATIONS OF AGRICULTURE AND METEOROLOGY.

It is obvious from the outline given above that the researches required by agricultural meteorology include a number of biological and meteorological observations, which must be carried on in a parallel manner and at the same point. There is no need of creating new organizations for this purpose; on the contrary, use should be made of already existing agricultural schools and stations which possess buildings, technical staffs, and land for the purpose of experiment. It is only necessary to provide these places with the necessary instruments, rain gauges, hydroscopes, minimum and maximum thermometers, geothermometers, trial balloons, etc.

When the conditions of the environment are uniform, as in Russia, for example, where the topographical conditions and those of climate are repeated throughout very wide zones, the number of the stations may be comparatively limited. In Italy, on the contrary, with the exception of the plain of the river Po, which is pretty uniform, the aspect of the country varies considerably from one point to another, even between very limited zones, so that it would be necessary to increase the stations to so great a number that the creation of such a service is impracticable.

But however capricious and variable the geographic distribution of those weather phenomena which involve damage to crops, the nature and significance of the problems of agricultural meteorology remain always the same. Therefore, agricultural experimentation having for its object the solution of the problems which have been stated and defined through the analyses made by Agricultural Meteorology can be conducted in a comparatively limited number of stations, provided we know with precision at what points and to what degree a certain phenomenon involves damage to a given crop.

Evidently then, the agronomic stations and the schools and institutes of agriculture distributed over a more or less restricted area, in all the civilized countries of the world, can be made to serve as first class stations of agricultural meteorology merely by the proper provision of special instruments. These may be complemented by other institutions which seem suitable.

### III. APPLICATION OF THE METHOD TO A SPECIAL CASE: THE CULTIVATION OF WHEAT IN ITALY.

For example, the meteorological phenomena capable of injuring the development of wheat in Italy are very numerous; thus in the southern part of the peninsula we have the following phenomena:

I. The hot dry winds (sirocco and "favonia") which at the ripening period (during the fifth sub-period) occasions scorching or parching. This produces a sudden ripening and actual drying of the grain, and while the plants are still vigorous the caryopses suffer from lack of nutrition, or even fail to form. This accident, which is especially serious in light soil where there is only a thin layer of earth which can be cultivated, in some years diminishes the crop in the space of a few days by 25, 30, or even 50%.

II. The lack of rain during the ten days or the twenty days preceding the formation of the ear.

III. Prolonged drought in the period directly following the sowing of the seed.

Infection by rust is of less importance, since it is but rarely and over very limited areas that excess of humidity in the spring is to be feared. Falling is almost unknown, since hard and semi-hard varieties having a short, robust stalk are cultivated in the islands and over most of Calabria and of the Basilicate.

In central and northern Italy, on the contrary, we note the following conditions of climate:

I. In the valley of the Po, and in the lower part of this region especially, the wheat almost always suffers from an excess of humidity, which causes serious infection by rust and corresponding diminution of the harvest.

II. Falling caused by the wind and by deluges of rain at the period of the formation and the development of the caryopses may lessen the yield by from 20 to 25%.

III. Finally, considerable damage is caused by late spring frosts. We are now endeavoring through the circuit of stations of agricultural meteorology to increase our present knowledge, which is comparatively general, by study of the following questions:

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[1] Bulletin of Bureau of Agriculture, Industry and Commerce, series B, p. 1-10, 1916. Bimonthly Bull. of Ital. Meteor. Soc., 3rd Series, Vol. XXXV., Nos. 6, 7, 8, p. p. 25-32, and Nos. 9-10, p. 39-42, 1917.

*a* The determination of a critical period of wheat in relation to the various meteorological phenomena mentioned above;

*b* The preparation of phenological charts;

*c* The preparation of weather maps.

As soon as the critical period has been discovered we can easily establish, by means of a comparison of the weather map and the phenological chart, the degree to which the plant under investigation suffers from the local conditions of climate. For example, if at A the earing of the wheat generally occurs about the 10th of May, and if in the last "decade" of April and the first "decade" of May the probability of drought is from 75 to 90% respectively, we perceive the reason why the average harvests in this locality are inevitably small.

When we have established the cause of the low yield there are three possible fashions in which this state of affairs may be remedied:

I. Change the phase corresponding to the critical period, and make the latter correspond with the time more favorable from the meteorological point of view. For example, the variety of wheat *f* at station A usually ears, as shown by the phenological chart, about May 12; furthermore, the probability of drought in the third "decade" of April and the first "decade" of May at A is equal to 90 and 95% respectively, as shown on the weather map. Herein we see the reason for rather low average yields. In the first and the second "decades" of April, on the contrary, the probability of droughts at A falls to 10 and 15% respectively. By planting earlier, or by choosing an early variety *f* so that the earing phase falls in the period from the 20th to the 26th of April, it will be possible to remedy this disadvantage at least in part.

II. Modify artificially during the critical period the meteorological conditions; for example, fight frost with smoke clouds, drought by irrigation, etc. In the fruit district of California brilliant results have already been obtained by forecasting the coming of a cold wave from 24 to 48 hours in advance, thus enabling the growers to diminish or entirely avoid the damage feared by burning heavy oil and other substances which envelop the trees with a thick, protective smoke.

III. Introduce or produce varieties more resistant to drought, frost, rust, etc.

The modern experimental studies in biology carried on in France, America, Sweden, Germany, Italy and elsewhere have proved clearly that it is possible, by means of crossing and subsequent selection, to unite in a single variety the good characters existing in two distinct varieties, and to eliminate the non-desirable characters. In each special case the breeder must seek to unite the character of "high productivity" with the character, "resistance to the most frequent factor of damage in the weather" in the given locality.

Thus at Svalof, in Sweden, Nilsson obtained varieties of wheat not only very resistant to cold, but at the same time admirably productive, by hybridizing the most productive variety having slight resistance to cold (English "Squarehead") with the native Swedish wheat which is extremely resistant to low temperatures.

This work of the acclimatization of non-native types, and of the creation of new types by means of hybridization and selection, will constitute the most important field of the activities of first class stations of agricultural meteorology. In selecting the latter, consequently, one should always make choice of already existing agricultural and agronomic institutes and not of meteorological institutes, which are capable of cooperating with the former but not of being the centre of new studies.

Let us examine an example which proves that "meterological-agricultural" study is not only necessary in cases of territory brought under cultivation for the first time, but that it is capable of giving excellent results, even in areas where intensive culture has long existed, by determining a better adaptation of crops to the climate of different regions.

In the Province of Bologna, in northern Italy, three varieties of wheat are cultivated on practically every farm: Riéti, Gentil rosso (fine red) Vilmorin's "never falling" Hybrid; these are distinguished by the following characters:

I. Riéti resists rust but easily falls; in favorable years, i. e., when not made to fall by storms, it produces 22 quintal per hectar;

II. Gentil rosso, very sensitive to rust and subject to falling; in favorable years, without excessive humidity or damage by storms, capable of producing 24 quintals per hectar;

III. Vilmorin's "never falling" Hybrid, subject to rust but resists falling; when the humidity is not excessive it is capable of producing 21 quintals per hectar.

The last two varieties are of recent introduction, and still other varieties which are now being studied in various agricultural institutes will eventually be added to the previous varieties, thus causing a promiscuity and heterogeneity of varieties which is not always desirable.

But why should we not limit ourselves, on the contrary, to a single variety—to the one which is the best adapted to the special condition of the climate of the given place? Practical farmers generally make the following answer, to wit, that there is no specially well adapted variety and none which has both faults at the same time, so that when one of them suffers from bad conditions in a given year, there will be another variety which will succeed and thus compensate for the loss on the former variety.

But this reasoning is false. The Gentil rosso when it does not fall produces as high as 24 quintals per hectar, while Vilmorin's Hybrid produces only 21. But the former readily falls while the latter does not. This falling ocasions a loss of five quintals per hectar, which reduces the crop to 19 quintals; and the probability of heavy floods of rain accompanied by wind, during the fifth sub-period, is 80% in the Province of Bologna. In a period of five years, therefore, the yield of the Gentil rosso would equal 24 plus (19 times 4) equals 100 quintals, while the yield of Vilmorin's Hybrid in the same period would be 21 times 5 equals 105 quintals. In the province of Bologna, consequently, where the probability of falling is 80%, Vilmorin's Hybrid should be preferred to the Gentil rosso, at least in places where the soil is rich and deep; but this preference does not yet exist in very many cases. When, on the contrary, the probability of storms in the fifth sub-period falls to 20% the Gentil rosso should be preferred, as the following figures show:

Vilmorin's Hybrid 21 times 5 equals 105; Gentil rosso 24 times 4 plus 19 equals 115 quintals.

IV. CONCLUSIONS.

*Agricultural meteorology is indispensable, therefore, if we would have an exact idea of the real productivity of any given species in a given region.*

The mere fact, for example, that a variety of wheat is cultivated by preference in a given place does not signify that the variety is the one best adapted to the locality. Growers often buy new varieties which sometimes entirely take the place of native varieties, but give way in a short time to still newer varieties, In all these cases, naturally, it is the character of "productivity" which guides the grower in the choice of seed; but the productivity is influenced in a very special fashion by conditions of climate, and, as a result, it varies from one place to another, so that the adoption or the introduction of a new variety ought to be preceded by painstaking study in agricultural meteorology.

This science achieves a double result:

I. It enables us to distribute the different varieties of a cultivated species in a better manner within their area of distribution, i. e., it assigns to each variety those regions which best suit it with regard to the local conditions of the climate;

II. It guides the breeder in his researches and experiments made with the object of combining in a single individual, in the most advantageous proportions, the character "productivity" and the character "resistance," i. e., to the most injurious meteorological phenomenon in the various regions.

This science comprises profound and extended efforts at the adaptation of crops to climate, which cannot fail to lead to positive results, at least in part, and the results, even though small, would be far from inconsiderable considering the size and complexity of the problem.

Unfavorable weather conditions in Italy reduce the harvest of grain by four quintals per hectar on the average; if we succeed by these methods in making a gain of one quintal per hectar this would represent the very considerable amount of 4,785,000 quintals.

What has been said with regard to wheat can be repeated for every crop; and what has been indicated for Italy can be repeated in every country of the world. Moreover, as we have seen, the circuit of stations of agricultural meteorology is already outlined by the institutions already in existence; it is only necessary to combine, co-ordinate and develop all this latent or scattered activity, so as to limit the expenditures required for the creation and maintenance of this new service to the community.

## The Hunting Spider

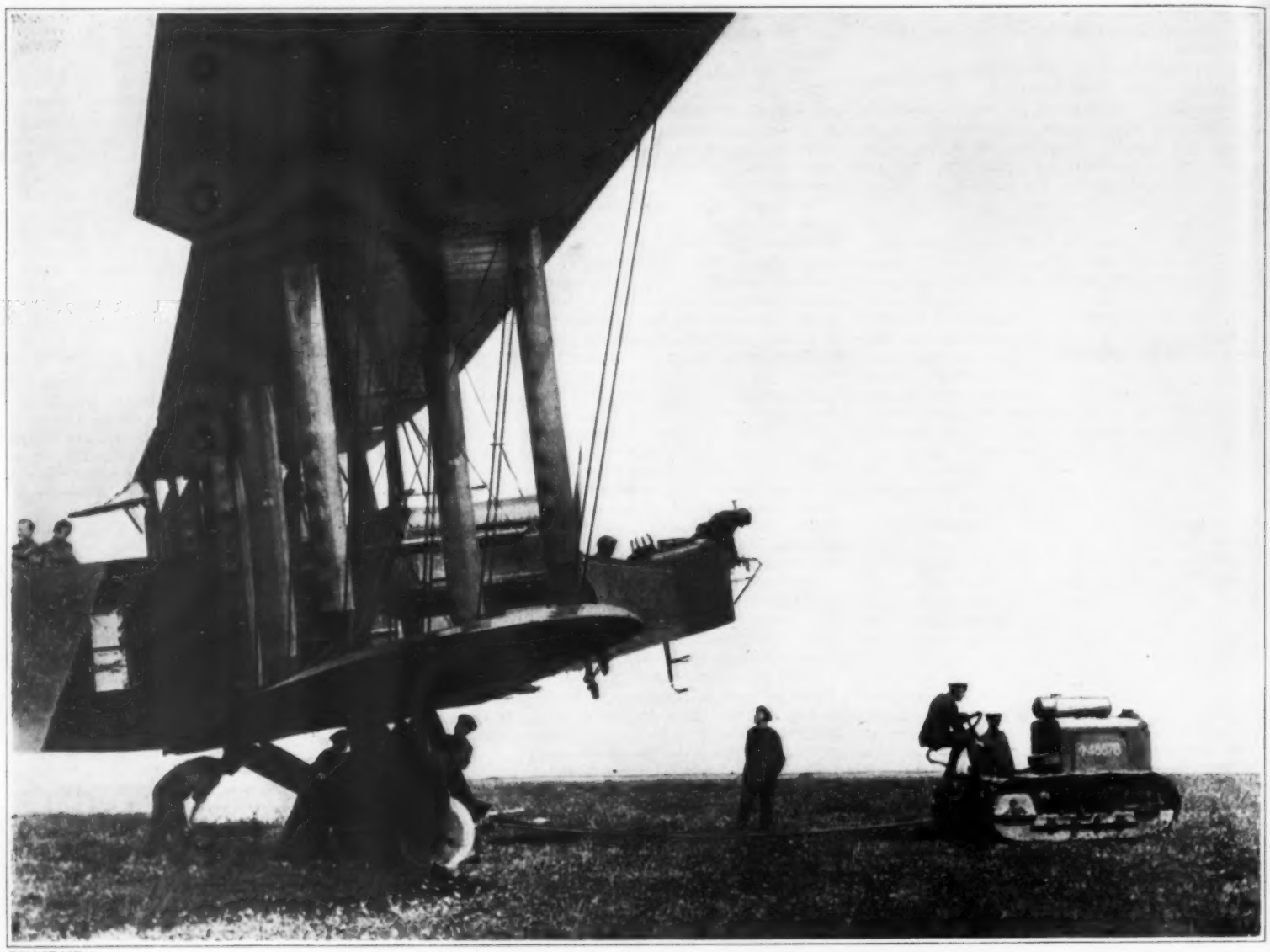
Most of us are acquainted with the tiny red spider that careers about the herbage with such amazing agility. He is a hunter *par excellence*, and quite puts to the blush his long-legged cousin that wambles over the dry moorland floor, his legs always, as it were, in his way, and ever aimlessly seeking for the land of nowhere. Doubtless his eyes being fixed in the middle of his back accounts for his ineptitude. He is also more noticeable for the fact that he himself is a veritable quarry, the hunter in this instance being secure in his immobility. The brilliant scarlet dots on him are not part of his own autogeny; they are six-legged parasites which even his immense legs are unable to brush off. One virtue accredited to him deserves mention, for more than one local weather-prophet swears by the "ettercap." And they are rarely far out either.

My favorite of the spider tribe, however, is one that has given me much cogitation. He seems quite too clever, for he apparently eludes the force of gravitation. This is the zebra spider (*Salticus scenicus*), a famous jumper. His gymnastic feats are not limited to solid earth, but take place on walls and ceilings or, indeed, anywhere upside down or vertical. Having caught one the other day, I took the opportunity to find out if his wonderful powers were understandable to us, so I put him under a bell glass, and gave him a fairly long fast. In the interval I had a good look at him. He is "spotted like a pard," the greyish markings resolving themselves under a lens to aggregations of oblong scales on his black body. Over all he has a "birsy" hariness that is quite fearsome; and the manner in which he clashes his pedipalps, or hands, together must prove very annoying to his enemies. Later he finds those appendages of great use, for after a meal he continually touches up his whiskers with them. Indeed, they are so flexible and gristly and so well furnished with brushes that it might well be supposed that that is their primary purpose, for they are of no military use whatever, however fearsome they may look. The time appearing propitious for my experiment of spider versus gravitation, I placed a fly on the ceiling of the bell-jar. Very seen he saw her; approaching nearer and nearer with movements that vividly recalled the stalking of a bird by a cat. Both being upside down I was quite sure he would never manage it.

However, I was so intent on watching the attitudes of the hunter and hunted that I omitted to observe a very important happening, indeed, the very thing that would explain what I wanted to know. In due time, doubtless when his fixed focus eyes—he has four by-the-by—synchronised with his leaping powers, he made his terrible leap. Instantly both were struggling in the air, suspended by a thread. This, then, was the secret. He was— and this was what I did not notice—anchoring himself safely with a life-line before the attack. This holding firm, all the rest of the struggle took place in mid-air. Then, with his fangs in the fly's neck, he regained the firm foothold. It was only then that I saw how, every few paces, the spinnerets attached the invisible thread to the glass so that no risks might be run. I could see the spinnerets perform the action; the thread I could not see, even under a powerful lens, so fine was it, yet so efficient, that it bore the weight of the struggling combatants immediately it was spun. On a horizontal surface this anchoring line would only be a hindrance, so that he must exercise a certain judgment in his procedure, measuring, as it were, all the risks involved in the audacious leap into the air. He rarely misses once he gets into striking distance. This, however, is always just his difficulty.—*D. W., in the Scotsman.*

## A Marriage Custom in the Sudan

In *Sudan Notes and Records* Mr. W. Nicholls describes a remarkable marriage custom in the Sennar province which is known as "stealing the fire." On the final night of the festivities the bridegroom goes to the bride's house escorted by a band of youths bearing torches. These torches can be lit only by fire taken from the bride's house, and this the relatives of the bride take every possible method to prevent. Some of the bridegroom's friends creep in secretly at night, or a body of them forces its way into the house to carry off the fire. The editor quotes as parallels the custom recorded by Sir James Frazer ("The Golden Bough," "The Magic Art," vol. II,. pp. 216, 320), in which fire is used as a fertility charm in marriage ritual. But this is not an exact parallel, and, assuming that the charm is in the interest of the bride, it does not account for the resistance made by her friends when the bridegroom's party endeavors to procure fire from her home hearth.—*Nature.*



British Official Photo

Towing a big modern bombing plane into position for a flight by a motor tractor

# Destruction from the Sky

## How Airplane Bombers Go About Their Work

An important factor in finally forcing Germany to her knees, a good many military experts are of the opinion, was aerial bombing.

The tremendous posibilities of destructive warfare and the very great material and moral damage bombing machines may accomplish was just, it might be said, beginning to be fully appreciated by the allies.

In brief, after a somewhat slow start, bombing finally came into its own and in numbers and interest it promised to outweigh all other branches of our military Aviation Service.

It has become a tactical and strategical arm of paramount importance, carrying destruction and dismay from the rear of the immediate battle line to the towns and factories of the far interior of Hunland, and it counts in its list of pilots and observers many of the most famous names in allied aviation.

The bombing plane operates in all altitudes, from 200 feet or less to four miles or more above the earth; and work which the days leave unfinished the nights complete. It is the latest and most powerful plane built, nearly equal in speed and climbing ability to the best of the much lighter pursuit machines. Heavily loaded for offense and armed for defense, it combines the best elements of other arms.

The start of an American bombing squadron from the French front on a raid into German territory was a spectacle to stir the enthusiasm of any American and inspire him with an appreciation of Uncle Sam's rapidly growing strength in the air.

The order given for the squadron to make a flight, the aviators hurry from the field to their quarters for their heavy arctic clothing, for it is terribly cold at times in the upper air.

In the turn of a hand they are back swathing and swaddling themselves to the eyes, tucking chocolate into their pockets (for they get hungry up aloft) or breaking open a fresh package of chewing gum, which helps to alleviate nervousness and has a steadying effect.

The last machine gun having been tested, the last propeller having been twirled until the engine starts, the commander gives an almost imperceptible wave of his hand.

Bombing airplane 1, bearing the flight leader, released by its restraining mechanics sweeps in a big curve across the field, "taxing" clumsily with its weight of bombs, to a position from which it can rise at the head of the group.

One by one the others follow suit, taking up position just behind and to the right and left of the leader until they are spread out like a huge covey of ungainly but marvelously colored birds.

As they wait they toss out rockets, which, despite the brilliant sunlight flare a blinding red and white. The test complete, they are ready for the start.

The noise of the motors rises to deafening proportions. The great covey begins to move, gains momentum as it speeds northward across the field, then one after another the machines "takes off" the ground. All the clumsiness of the "taxing" gone. The airships have become graceful birds in fact.

Swiftly they rise, while still within sight, to a great height, looking for all the world like a flock of geese with the leader at the neck of the formation. Later on, when about to cross the Hun line, they draw closer together into a compact tightly knit V shaped group, but always following, whether to left or right the two little white pennants streaming out from the leader's machine.

Flying in formation makes it possible for them to penetrate to a great distance inside the enemy's lines and to repulse successfully attacks without abandoning the mission.

It is rare that bombing squadrons are composed of more than eight planes as larger groups, it has been found, are difficult to lead well and greatly reduce the horizontal and climbing speed of the squadron as a whole.

At all times the bombing planes are under the orders of the flight leader, who invariably flies in the leading machine. He may be either pilot or bomber. The secondary flight leader, who replaces the leader if the latter is obliged to fall out or is brought down, may occupy any position in the group.

The cardinal rule of formation flying is that the group shall never be broken. In passing over the objective, as well as during an attack by enemy machines, the formation is held as rigidly as possible. The direction of the shooting lies of course in the care of the bomber in the leading machine, while that of range may be settled also by a signal from him, or may be left to each individual bomber. Present bombing sights render a fair precision possible even in the most difficult circumstances.

When several groups take the air at the same time, they generally follow in sight of one another at intervals of a mile or less, in order to be of mutual aid in case of attack. They frequently execute a combined operation, converging upon the same objective, or attack neighboring points at the same time. If, on the other hand, the groups do not leave together, an interval of at least two hours is allowed to elapse between them in order that the enemy's pursuit planes which have taken the air against the first flight shall have returned to the ground before the second flight passes over.

When a day bombing squadron starts out they fully realize that they cannot operate without fighting combats with enemy planes being almost a certainty.

This has been particularly true in recent months, since the development of the now famous Fokker triplane, which, while not as fast as some of the other pursuit machines, has a climbing speed which sur-

British Official Photo

**One night's supply of bombs for an air raid**

**Attaching bombs to plane in preparation for an expedition**

passes that of any other plane on the front, and can consequently attack with exceptional vigor from below. The enemy uses these triplanes in large numbers, frequently as many as twenty or thirty at a time, and it is a rare thing to accomplish a raid of any length without a pitched battle somewhere along the route.

In many particulars night is quite different from day bombing. Formation flying is almost impossible at night. A squadron usually receives orders to hold itself in readiness several hours before hand and the machines are loaded, warmed up and drawn out of the hangers. When final orders arrive they take the air individually and at successive intervals, generally three to five minutes apart, each machine, its motor humming sullenly, rolling momentarily into the flare of the field lights, which throw its least details and the faces of its occupants into high relief. A sharp signal from the field officers, a wave of the pilot's hand, the sound of the motor grows suddenly heavy and the huge ship glides slowly and majestically off. The same procedure follows for each of the remaining machines.

The summits of the highest mountains do not give an impression of solitude equal to that experienced by those who fly at night. Deafened by the roar of his motor, his eyes straining into the night world, the flier proceeds upon his mission. On crossing the enemy lines and at the noise of the raider's motors, all the enemy's lights for a radius of fifteen miles or more are extinguished. The sharp rattle of a machine gun and the cough of the anti-aircraft gun announce that the enemy is getting into action. Bullets whistle, shells burst, the enemy's searchlights put forth their long fingers, creep about the sky, cross and recross, clothing the heavens in a Scotch plaid of mingling rays. The machine flies straight ahead. Its mission is to find its objective, launch its bombs upon it and return as quickly as possible. The artillery defense of the enemy is dangerous only if concentrated. If the ray of a searchlight catches and follows it, it zigzags or sideslips back into the darkness.

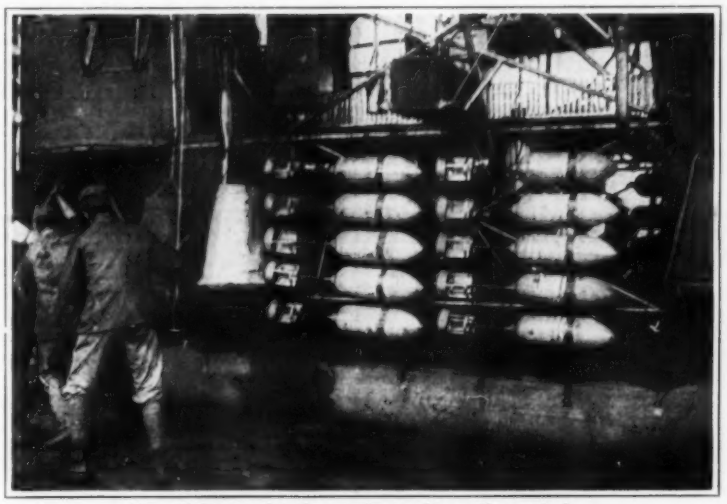
When the objective is small and well defended, the aviator blinded by the searchlights and hemmed in by shrapnel, plays hide and seek with his hunters. He withdraws, returns, withdraws again, and waits for his chance. Old hands at night bombing never lose their calm. They know that the defence is always a little behind the attack. When the objective is large the aerial defense can do nothing.

The homeward journey of the bombers at night is accomplished in the same manner as the outward trip.

Those who left last who did not benefit by the surprise of the attack, are awaited with greatest anxiety. Those already home count the minutes and watch for daybreak. Such remarks as these are heard: "He ought to be here. He must have had a forced landing. So-and-so landed in Germany one night, repaired his carburetor and arrived two hours late. He's equal to such a trick." A pale light breaks in the east. Eyes search the heavens and ears are strained for the slightest sound. Ten minutes, five minutes more, ten minutes more, the sun rises, and the watchers know that certain comrades will not return.

Such is the rôle of bombardment aviation today, but if the war had continued for any length of time the imagination is hardly equal to picture what bombing would later be able to accomplish.

Machines are even now in contemplation of nearly 2,000 horse power which may carry more than three tons of bombs. Many predict these planes will travel with ease across the Atlantic.



**One of the two bomb carrying racks on Caproni plane**

## Rheostat Design

If a rheostat is connected in series with the load, small currents cannot be obtained with a given voltage supply. If the load is shunted across a portion of the rheostat on the potentiometer principle, only a fraction of the full current capacity is available. To secure the advantages of both methods of connection there must be a complete rewiring of the circuit, involving loss of time and possible injury to the rheostat and other aparatus when used by students. These difficulties have been eliminated in a new design in which the line and load terminals are separate, and the change from series to shunt connection is made by closing a simple switch. With the switch open, values of current up to the full capacity of the rheostat may be secured; with it closed, small values of current and voltage, down to zero, are obtainable. A new feature of the design is that by proper choice of resistance and winding the voltage and current ranges in the two arrangements may be made to overlap for any load, no matter what its resistance. Thus, with a 110-volt supply and a load of 15 ohms, a rheostat of 30 ohms and a current capacity of 5 amps., the series arrangement permits currents from 2.5 to 5 amps. to be obtained, while the shunt arrangement gives currents from 0 to 2.5 amps. For a given voltage and size of tube on which the wire is wound (watt-capacity) there is one winding, and only one, which will give the max. current capacity and yet provide for any load, overlapping of the series and shunt ranges. With the ordinary rheostat there is no means of knowing with what voltage it can be used, nor is there any indication as to whether it is capable of giving overlapping ranges. With the new design, voltage and current capacity are made the determining characteristics, and the resistance is incidental. If the windings are properly worked out the resulting current capacity is the greatest which can be secured with the given voltage, and within these max. limits all values of current and voltage down to zero may be secured, no matter what the load. Thus the new type is not only easy to connect and to operate, but it possesses the highest possible efficiency.—*H. L. Dodge in Proc. Ia. Acad. of Sci.*

British Official Photo

**Three types of aerial bombs used by the Allies**

## Heat Conduction and the Gas-film Theory

In 1912 Langmuir showed that the film of quiescent air adhering to incandescent wires is 0.17 inch thick. The author finds that at low temperatures the equivalent film thickness of water is about 0.05 inch, in water which is not stirred mechanically. The equivalent film thickness of steam is apparently much less than that of air, which may explain why water in the ashpit of a boiler increases the fuel efficiency under certain conditions. As used by the author, the term "equivalent film thickness" means that thickness which gives the actual temperature difference assuming for simplicity that each film conducts heat on a linear temperature gradient, as though it were a solid. An example in the original shows the much greater heat resistance offered by the surface air-films compared with the heat resistance of window-glass. Double glazing is so effective in reducing heat losses because there are four air films, only one of which can be reduced in thickness by a strong wind. The author illustrates the application of the film theory to the design of windows and heat-insulated walls, and describes a new type of heat insulator in which the space between hermetically sealed walls is filled with granular or fibrous material and a gas of low conductivity, such as $CO_2$ or $SO_2$; such an insulator has more than twice the heat resistance of an air-film insulator of equal thickness. —*Note in Sci. Abstr. on an article by H. T. Gillette in Eng. and Contracting.*

## The Shortage of the Supply of Non-Phosphoric Iron Ore in Europe*

ALREADY in the pre-war years the supplies of high-class hæmatite to the iron-smelting districts of Europe from the nearer sources were getting short, and the time was in sight when, for iron ores low in phosphorus such as are required for the production of the "hæmatite grade" of pig-iron demanded by those who make steel by the "acid" process, we shall have either to turn our attention to sources of supply which are less readily accessible, or so to improve metallurgical processes that, from ores which are abundant in closer proximity to the coalfields, trustworthy substitutes for "Bessemer-grade" acid steels can be economically produced.

Within the British area there is a remarkable absence of any considerable concentration of iron ore among geological formations of pre-Carboniferous age. The non-phosphoric hæmatites of the Carboniferous Limestone district occur as veins and impregnations, and extend some little distance downwards among these older rocks, but in their distribution they are limited to a narrow belt of country which ranges north and south through the English Lake District and the Forest of Dean, and are probably of post-Carboniferous date. They are less regular in their distribution, and therefore more expensive to exploit, than are the bedded ores associated with the Coal Measures or interstratified in thicker masses among the Jurassic rocks, and the shortage of home supplies of hæmatite has already long been felt.

In former days clay-band and black-band ores, interstratified among the Coal Measures, afforded the main supply of English and Scottish iron, but when steel superseded wrought-iron as the ordinary material for constructural engineering, economic conditions brought about the diminution of iron production from these ores, and though there lie in reserve more than thirty thousand million tons of such ore among our Coal Measures, that source of supply does not at present represent to our ironmasters a national asset which has any great marketable value.

Along the outcrop of the English Jurassic rocks between the coast of Dorset and the Cleveland Hills there is nowhere any lack of low-grade iron ore. In the neighborhood of the Humber it is the Lower Lias which carries the ore-bed, but generally the Middle-Lias is the more prolific horizon. In Northamptonshire the great development of iron ore is in the basal member of the Inferior Oolite series, and at Westbury, in Wiltshire, and throughout the southern counties, the most important development is in association with Corallian rocks. "Just as the Carboniferous is the great repository of Great Britain's fuel wealth, so the Jurassic is the bank which holds our fluid reserves of iron ore. The gilt-edged securities of Cumbrian hæmatite are sound, but not unlimited in amount; while the market for the vast quantities of the clay-band and black-band ores of the Coal Measures must needs be written off. Our engineers prefer the produce of the hæmatite, but there is a shortage, and the price is therefore high. There is plenty of the low-grade phosphoric ore available and cheap. Surely it is not beyond the skill of our metallurgists to make use of it and obtain from it a product which on its merits will overcome the prejudice of the British engineers. This is the only domestic solution of the problem of the home shortage of non-phosphoric iron ore."

Probably it has been realised by few that the total quantity of metallic iron obtained from iron ore brought by ship to Britain *plus* the weight of metal imported in the semi-manufactured state has for twenty years past been in excess of the quantity smelted from ores wrought in British mines and quarries. Iron ore as imported is generally a fine, selected, high-percentage ore, but in the average of home ores the percentage of iron is compulsorily low, and the tendency is downwards, the average percentage of metallic iron contained in them have declined from 34.7 to 32.1 in the last twenty years.

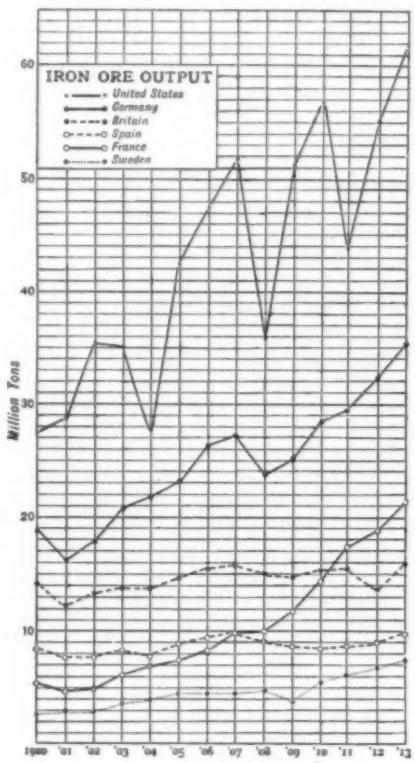
In the pre-war years the demand for hæmatite among the ironmasters of the Rhineland was, as in Britain, on the increase, and in consequence the centre of gravity of the hæmatite supply showed signs of a gradual shifting southwards and eastwards.

During the last decade many of those famous iron-ore bodies occurring in association with limestones equivalent in age to the upper part of the English Gault, which were opened up close to Bilbao, in northern Spain, early in the 'eighties, have become exhausted, and at the pre-war rate of depletion the known ore reserves of that district could scarcely have lasted more than another score of years. Other valuable metasomatic hæmatite masses have been discovered further to the westward, along the Pyrenean chain, and only wait for development until better means of transport to seaboard are provided. In southern Spain the present century has seen the beginning of active development of iron mining, and in the pre-war year an output equal to more than half that from Bilbao was thence exported.

The metasomatic hæmatites of Algeria, Tunis, and Morocco follow the foothills of the Atlas range. The well-known mass at Beni Saf promises to become exhausted if worked at pre-war rate for another half-dozen years, but other high-class ore bodies have been discovered along the line of the same unconformity, where Mesozoic sediments rest upon the ancient schists and gneisses, and are ready for exploitation when railway facilities are provided. In Tunis the ores worked are often manganiferous, and some of them, though apparently true hæmatites, carry more than a trace of phosphorus.

Hæmatite masses formerly worked on the island of Elba and on various of the Grecian islands in the Ægean Sea are either exhausted or likely to become exhausted, if quarried at the pre-war rate, within the present generation.

Produce from the Minette orefield of Lorraine has




**Curve of Iron ore output of the United States and Europe**

generally been converted into metal in Germany, Belgium, or France before it reached Britain, and in consequence, the great importance of this orefield as a source of supply to British markets is often overlooked. It would appear that certainly far more than a million tons of metal brought into this country in each of several of the pre-war years might be traced back to a source of origin in the bedded Jurassic sediments of Lorraine. For the smelting of each ton of this imported metal, probably at least three tons of ore and two tons of coal (from the Hercynian belt of coalfields) must have been consumed, and it therefore appears that for quantity of mineral mined to supply the British market the area taken from France by Germany since 1870 must have held a place equal to, if not in front of, the ironfields of Spain. The iron ore wrought in Lorraine occurs as a series of beds, interstratified among Allenian (Toarcian) shales and limestones, almost identical in age with the Northamptonshire iron ores. The outcrop of the Minette formation extends from the southernmost tip of Belgium through the borders of Luxembourg with France and German Lorraine, southwards at an average distance of about three miles inside the 1914 German border as far as Metz, and crosses into Franec just east of Nancy.

Of the workable orefield about 160 square miles lie on the German side of the border, fourteen square miles in Luxembourg, and 208 square miles on the French side. The "Grey Bed" ores from French Lorraine are almost perfectly self-fluxing in the blast-furnace, and yield a pig-iron particularly suitable for steel-making by the basic process. According to German authorities, quite the best of the ore comes from the deeper mines beneath the Briey plateau, and had not the German ironmasters been bound by agreement to continue the payment of royalties to the owners of minerals in Germain Lorraine and Luxembourg, they would have abandoned these workings in their own country and smelted the bulk of their pig-iron from the produce of the Briey mines. Since the late 'eighties, with the perfecting of the basic process, the Lorraine district has established itself as the source of the cheapest supply of steel in Europe, and in the pre-war year the output from it was not much short of fifty million tons of ore. From German Lorraine about 300 out of 2,000 million tons, and from France about 200 out of 3,000 million tons proved, are won. "Truly, the Lorraine iron-ore district is an asset of the highest national importance, and there can be no doubt that, when official Germany has allowed rumors of her arrogant peace terms to be bruited, the industrialists of the Rhineland are at one with the military caste of Prussia in classing Briey and Longwy as essential strategic points."

Despite their nearness to the ports of Britain, the orefields of western France have not received from British ironmasters the attention they deserve, and more than two-thirds of their produce was, in the pre-war years, exported to Germany. The ironstone formation there is of Upper Arenig (Llanvirnian) age, and somewhat phosphoric in character. In the Normandy district, within sixty miles of the port of Caen, an ore reserve exceeding 200 million tons has been already proved, and the output of the mines of that district is expanding rapidly. The more southerly region north of the mouth of the Loire, in Anjou and Brittany, is as yet less well developed, but there is great hope of discovery of abundant rich ores of quite similar type. Western France is dependent upon English coal for fuel, and it is argued that vessels carrying coal thither should bring return cargoes of iron ore to British blast-furnaces.

For the production of "Swedish iron" the magnetite ores of central Sweden are generally selected by hand, or, after crushing, are concentrated by the wet magnetic process and briquetted. The supply or non-phosphoric magnetite in Sweden is very limited, and the immense magnetite lenticles of Norbotten, in Lapland, are of far greater importance to the Swedish export trade. The ore mass of Kirunavaara is one of the largest in the world, and is more than five miles long. In general, this, as also the other Lapland magnetite masses, carries a good deal of fluor-apatite, and being very dense requires a strong coke to carry its burden in the blast-furnace. For this reason, and because the produce from the Lapland mines requires to be converted into steel by way of the basic process, more than four-fifths of the ore exported from Sweden has found its market in Germany and Belgium.

In Norway the ore masses associated with the ancient schists are generally of lower grade than those of Sweden, and require to be crushed, concentrated, and briquetted to make them suitable for export, and few of the mines have yet advanced to the producing stage. From Sydvaranger, near the shores of the Arctic Ocean, on the borders of Russia with Norwegian Lapland, crushed ore is being successfully concentrated and exported. Some hundred million tons of available low-grade magnetite have been proved there lying in reserve.

Previous to the war produce from the orefields of North America affected the British market rather as a commercial competitor in outside markets than as an alternative source of supply. Since the outbreak of war, however, the British metal market, in former times largely supplied from the orefields of Lorraine, has had to replace its stock with steel and iron smelted in America from American ores. The "banded jasper" ironstone formations occur in the midst of Algonkian and Archæan sediments in the region of the Great Lakes, and segregation of specular iron ore in these formations has taken place along belts determined by tectonic folding. Largest of all the ore bodies in America are those of the Mesabi range, which district is responsible for nearly two-thirds of the total U. S. A. production. For magnitude of present output, as for gross quantity of metal yielded in the past, the Lake Superior region holds precedence over all the ironfields of the world. The available reserves there are enormous, and have been variously estimated at betwen 2,000 and 3,500 million tons, with a further 70,000 million tons of lower-grade specular material also in view. The Clinton oolitic ironstone of Silurian

*Abstract of the Howard Lectures delivered before the Royal Society of Arts by Prof. W. G. Fearnsides, Sorby Professor of Geology in the University of Sheffield. Reprinted in *Nature*.

age in the eastern States has many features in common with the Minette series of Lorraine. It is worked extensively in the Birmingham district of Alabama, and as a producer of basic pig-iron its importance is increasing rapidly.

The ironfields of the Overseas Empire are separated from home furnaces by distances too vast for it to be economical to bring so low-priced and bulky a commodity as iron ore to compete with the produce from ironfields in the European countries which have no coal. In Canada, Australia, South Africa, New Zealand, and India, iron is already being smelted at a cost less than it can be brought in from Europe, and in due course we may expect to see local iron industries develop, perhaps to such an extent that outlying portions of the Empire may send manufactured or semi-manufactured metal to supply the British market.

Among the world's great ironfields which are supplying their raw materials to the iron and steel industries only those in which the ore is to some extent phosphoric have been able since the beginning of the present century to increase their output on an extensive scale. The development of iron-mining in the various European countries and in America is shown on the diagram accompanying.

The chief natural advantages which have enabled this country to outbid foreign rivals in the overseas markets for non-phosphoric hæmatite are the native wealth of the home supply of fuel, and the accident of geography which sighted our magnificent coalfields near the harbors of our coasts. The high quality and cheapness of the fuel have enabled this country to maintain the supremacy of its mercantile marine throughout the age of steam, and this has been the dominant factor in securing to our ironmasters their ample hæmatite supplies. Meanwhile, the Germans, drawing the bulk of their ore supplies from deposits in closer proximity to their coalfields, have been able at very low prices to put on the market steel which is sufficiently satisfactory made from the Minette ores of Lorraine; and in the markets of the world this product has largely supplanted the lower grades of acid steel. British ironmasters, who were the last to feel the pinch of hæmatite shortage, have foreseen little commercial advantage to be obtained by smelting the cheaper low-grade supplies of home phosphoric ores, and have been reluctant either to reorganise or to extend their works in order to compete for low-grade trade, and only for high-quality tool and special alloy steels has the British Empire continued to supply her former proportion of the world's demands. Beaten in competition for the non-phosphoric hæmatite supplies, only available from overseas, Germany perfected the basic method of steel refining, and has certainly made the best of the mineral supplies she had at hand. America also has recognised that it is cheaper to work up ores which are abundant and occur in large masses in the neighborhood of existing transport routes, and most of her recent steel works extensions have adopted the basic open-hearth process of steel-aking. It has paid both Germany and America to adopt the basic process to provide a bulk supply of steel, and it should be equally profitable for this country to develop a part of its steel-making practice along similar lines, and from home Jurassic ores to produce at least sufficient metal to take the place of the two or more million tons of semi-manufactured metal which until lately was imported from abroad.

## The Early History of the Solar System

A COMMON feature of the older theories of the origin of the solar system is that they all suppose it to have been derived from a more or less symmetrical rotating nebula in a gaseous or quasi-gaseous state. By some process, the details of which differ in different theories, this mass is supposed to have condensed locally to form the sun and planets. A recent paper by Jeans has indicated a way of examining whether such condensation is possible. Viscosity is insufficient to cause a mass so large as the primitive nebula to rotate like a rigid body; each part would revolve practically independently around the centre under gravity, and the matter near any point, on account of the *differences* between the velocities of different parts, would be in a state of rotation with an angular velocity different from that of its revolution as a whole. It is, however, easily shown that the two are of the same order of magnitude. Now a mass cannot condense locally unless the density is so great that mutual gravitation is enough to balance the centrifugal force due to the rotation, and this indicates that, before condensation started at distance $r$ from the centre, the density there must have been at least comparable with the mean density of a sphere of radius $r$ and mass equal to that of the sun. Planets having been formed at many different distances from the sun, it follows that the mass must have originally been widely distributed through the system. The distribution of density and velocity being thus known within sufficiently narrow limits, it can be shown by the principle of the constancy of angular momentum that if planets of the sizes of ours were formed, the resulting central body could not possibly rotate so slowly as the actual sun. There is no agency capable of reducing this rotation, and it seems necessary to abandon completely those hypotheses that require the solar system to have been formed by the gradual condensation of a nebula.

We are led to inquire next whether planets could come into being by a more rapid or catastrophic process. Projection from the sun is not a possible origin, for a body started in this way must necessarily strike the sun again on its return and be reabsorbed; further, there is no reason why all should revolve in the same direction. The tidal theory appears to give a better account of the present state of the system. According to this, a star much more massive than the sun approached it very closely, and raised on opposite sides of it two projections, just as the moon raises tides in the earth; but the scale of the disturbance was in this case so enormous that the sun's gravitation was unable to prevent a rupture from occurring. Thus either one or two streams of matter were shot out in a time comparable with a few months or years. Being longitudinally unstable, they broke up into a series of detached masses, perhaps before the parts projected later had actually separated from the sun. That such rupture could occur has been proved by Jeans. The attraction of the disturbing body produced the direct revolution (in the same sense as the motion of the star relative to the sun); some of the revolving matter returned into the sun and gave it a direct rotation. The angular momentum thus acquired was, of course, derived from the transverse motion of the disturbing body relative to the sun.

The size of the deformed body has little influence on its chance of being broken up. Thus the detached masses might well have produced systems of satellites and developed direct rotations in the majority of cases, though complete uniformity could scarcely be expected on account of the number of complicating factors. The fission would cease when the star had receded a sufficient distance; thus the outer nuclei, being the first ejected, would produce most satellites. It seems possible also that some of these would be formed when the nucleus and the sun were on opposite sides of the star, and that the motion would therefore be retrograde. All the bodies, having recently formed part of the sun, would naturally be very hot.

The system after the passage of the star would therefore include a central sun surrounded by a number of heated planets, moving in direct orbits, and attended by satellites; the most remote planets would have most satellites. The rotation of the sun would be direct; the rotation of each planet would be in the same sense as the revolution of most of its satellites, and in most cases this also would be direct, though a few exceptions might well occur, especially in the outermost sub-systems. In every point this agrees with the existing solar system. The heated interior of the earth, the building of mountains by compression, and the present heated state of the greater plants are readily accounted for. The occurrence of three retrograde satellites on the outskirts of otherwise direct sub-systems presents a difficulty, but not, I think, a serious one.

In addition to the planets and satellites, however, there would be a considerable amount of gaseous matter too light to be condensed into the nuclei, and probably consisting mainly of hydrogen. This would be pushed round by the planets as they moved, but its resistance to oscillatory motions would steadily reduce the eccentricities of their orbits, which would initially be considerable. At the same time its own viscosity and diffusion would cause it partly to dissipate into outer space and partly to be reabsorbed into the sun. The zodiacal light is probably the last remnant of it. The actual eccentricities of the planetary orbits being now small, but definitely different from zero, it seems that the time the medium took to degenerate and the time needed to produce a considerable effect on the eccentricities must have been of the same order of magnitude. These are capable of being estimated in terms of the density of the medium, the first being proportional and the second inversely proportional to it. Thus the condition that they are of the same order of magnitude makes it possible to estimate very roughly both the density and the time needed for the changes, which is found to be of the order of $3 \times 10^9$ years, as nearly equal as could be expected to the age of the earth indicated by its radioactive constituents (about $1.6 \times 10^9$ years). At the same time large condensations would form around the larger planets, and the resistances offered by these would be so great, being proportional to the squares of the masses, that their eccentricities would diminish rapidly. Thus it would be expected that, on the whole, the larger planets would have smaller eccentricities than the smaller ones; this is the case, Mercury and Mars having larger eccentricities than Jupiter, Saturn, and Uranus, and the earth than Neptune. Venus has a somewhat smaller eccentricity than Neptune, but otherwise the agreement is remarkable.

It is certain that on the tidal theory the primitive nuclei must have been very hot, and probably fluid. Whether the larger ones were liquid or gaseous is very doubtful, but the smaller ones, including the asteroids and most of the satellites, can be shown to possess too little gravitative power to have been able to hold together in the gaseous state, and must therefore have been liquid or solid at the start. The satellites probably liquefied almost as soon as they were expelled from their primaries or from the sun, on account of the reduction in temperature caused by the release of pressure; solidification would occur more slowly. The origin of the asteroids presents greater difficulties. They may have started as independent planets of exceptionally small size; but the fact that none of their mean distances is greater than that of Jupiter, and only one is less than that of Mars, indicates a closer relationship between their origins. Several possible explanations can be advanced; the writer inclines to the belief that they were formed by the close approach of a primitive planet to Jupiter, leading to tidal disruption.

The large size of the moon relative to the earth suggests a fundamental difference of origin between it and the other satellites. It seems likely (indeed, on the theory of a formerly heated earth it is almost certain) that it was once much nearer the earth than it is now, and has receded on account of the friction of the lunar tides. It is natural to think that just before this state of motion with a comparatively small separation between their surfaces the earth and moon formed one body. The rotation would then be so rapid that the longest free period of the mass was nearly equal to the period of the semi-diurnal solar tide, which was consequently enormously magnified by resonance; and it is highly probable that the deformation became so great that the mass separated into two parts. This is not the only conceivable origin of the moon that would be consistent with the tidal theory; but several peculiarities in our sub-system suggest that it is the most likely. No other satellite in the system can have been formed in this way.

As has just been remarked, lunar tidal friction has probably been the predominant cause in the evolution of the earth and moon. No other satellite can raise tides of such importance; but those raised in Mercury by the sun must have been much more effective in reducing the rotation of this planet. Now from the fact that Mercury has no satellite we may infer that it never rotated so fast as the earth did before the moon was formed; and therefore the solar tides will have been able to reduce its rotation so as to make it always keep the same face towards the sun, which again agrees with observation.

Every satellite except the moon has probably been more influenced in its orbital motion by the resisting medium than by tidal friction. The most striking effect of the medium being to reduce the eccentricities of orbits, this accounts for the almost perfect circularity of the orbits of most satellites, especially those nearest their primaries, where the density of the medium was probably greatest. The effect of tidal friction on the eccentricities is not certain, depending on certain unknown physical quantities.

It may be said finally that at every point where the tidal hypothesis has been tested it agrees with dynamical theory and with observation. Several facts otherwise unaccounted for are explained by it, and nothing has yet been discovered to be definitely opposed to it, though a few difficulties, such as the origin of comets and meteor swarms, still remain.

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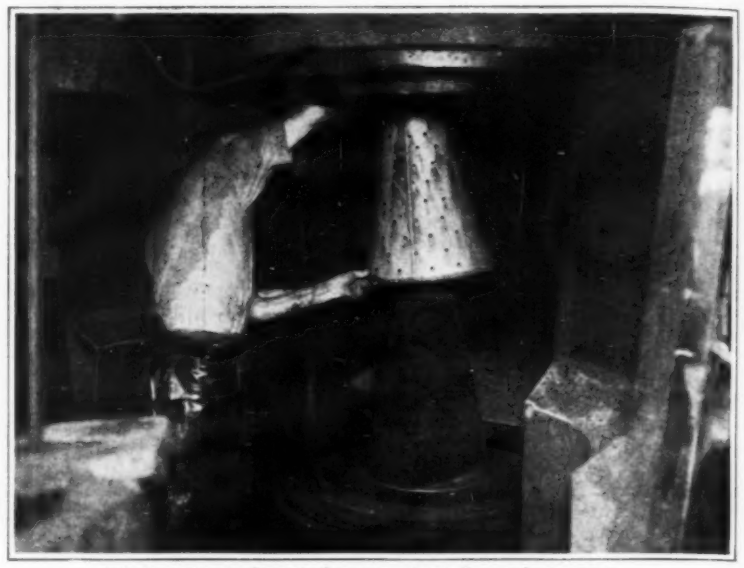
Harold Jeffreys: "The Resonance Theory of the Origin of the Moon," Monthly Notices, vol. lxxviii., 1917, pp. 116-31; "On the Early History of the Solar System," *loc. cit.*, pp. 424-41.—HAROLD JEFFREYS, in *Nature*.

The fur required for each hat is accurately weighed



The loose fur is deposited on a perforated cone by vacuum

# Making Hats for Our Doughboys

## An Elaborate Process Requiring Great Manual Skill

THE sombrero hat of the American Soldier is a familiar sight in every corner of our land today, and although the new service cap, developed by the British, is almost universally worn abroad, our familiar style of head covering will probably continue in use in this country, as it has been found to be well adapted to our climate, especially in the southern portions of the United States.

Hat making is a very ancient art, and it is interesting to note that, while a number of improved methods for performing the various operations have been perfected, it still remains to a very large extent a manual art requiring skilled handwork, and that machinery has only a subordinate place in the industry.

The material of which these hats are made is the fur of rabbits, or "conies", hares, musquash, beavers and the South American nutria, and as none of these animals are of large size, it will be appreciated what an enormous number of them are sacrificed yearly to provide head coverings for a larger portion of the world's population—for the same material is required for the ordinary stiff felt hats that is used for the soft soldier hat.

The first operation, when the fur-bearing skins come to the factory, is to wash them thoroughly with whale oil soap, after which the long, coarse hairs are removed, as they would make the surface of the hat too rough. Then the skins are treated with nitrate of mercury, or "carroted," to give the hair its felting properties; after which the fur is shaved by machines, and goes to the sorters, who each pick out the portions suitable for hats of different qualities. Then the fur is laid aside to season.

After seasoning the fur is mixed in certain proportions to produce the required texture, and the mixture goes to a machine that thoroughly blends the batch by blowing it about in an enclosed chamber. To make a hat a carefully wieghed portion of the mixed fur is put into a chamber that contains a tall copper cone that is perforated by innumerable fine holes. The chamber being closed, the fur is agitated by a blast of air, and at the same time air is sucked out of the chamber, through the cone, by an extractor. The flying fur is thus drawn onto, and deposited on the copper cone, and as the cone revolves constantly during the process, a very even layer of fur is obtained, the hairs being closely intermeshed, locked or felted. When the required thickness of film is secured, a closly fitting metal jacket is placed over the cone, and the whole is immersed in a vat of boiling water, which felts the fur, causing the hairs to mat and lock together. This makes it possible to handle the crudely formed and fragile cone of fur; but still further shrinking and felting is necessary, as the cone is about three feet tall, and too thin for practical purposes. To effect this a number of the cones are piled together and wrapped in burlap, and the pile is alternately dipped into boiling water and passed between rollers, an operation that reduces the size of the embryo hat, and at the same time makes the fabric thicker and firmer. The hats then undergo still another shrinking, which is carefully done individually by skilled workmen, and this reduces them approximately to the required size. They are, however, still in the form of a sharp cone, and they are now shaped in an ingenious machine which has a number of metal fingers that draw the crown down over a heated block, and at the same time stretch the brim to shape, the operation being assisted by dipping in hot water as before.

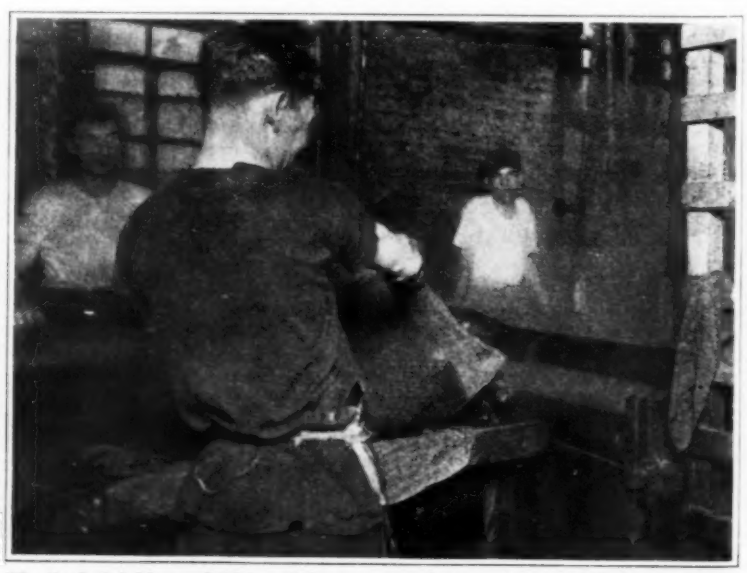
The hat is now ready for the finishing processes, the first of which consists in smoothing it on a rapidly revolving emery roller which removes all roughness and irregularities in thickness. This is a very delicate process, and requires a workman of great skill and judgment as the slightest mistake would make it worse than before, and it is very easy to grind a hole through the fabric, an accident that cannot be remedied, and the hat is ruined. After grinding, the hats are singed over a pan of burning alcohol to remove the loose hairs that stand up from the surface, and after this they are given their final form in a heated blocking mold under considerable pressure. The final process consists in trimming the brim to shape by a rotary cutter, and sewing on the sweat bands and the band or cord around the crown.

The accompanying photographs show the above described processes, and constitute an excellent history of the making of a hat.

### The White Ant

IN *Sudan Notes and Records* (Vol. I, No. 3, July, 1918) a plea is made on behalf of the white ant, which has naturally acquired a bad reputation among European residents. The characteristic feature of the climate of the Sudan is the rapid growth of vegetation promoted by seasonal rains or artificial irrigation, followed by a period of drought and desiccation. The white ant attacks vegetation only when it is weakened by drought or disease, and in that case the sooner it is destroyed the better. But for the activity of the white ant the whole of the fertile parts of the Sudan would, in a very few years, be covered with an impenetrable layer of dead vegetation; and the only alternative method to clear it off would be by the agency of fire, the dangers of which are obvious.—*Nature*.

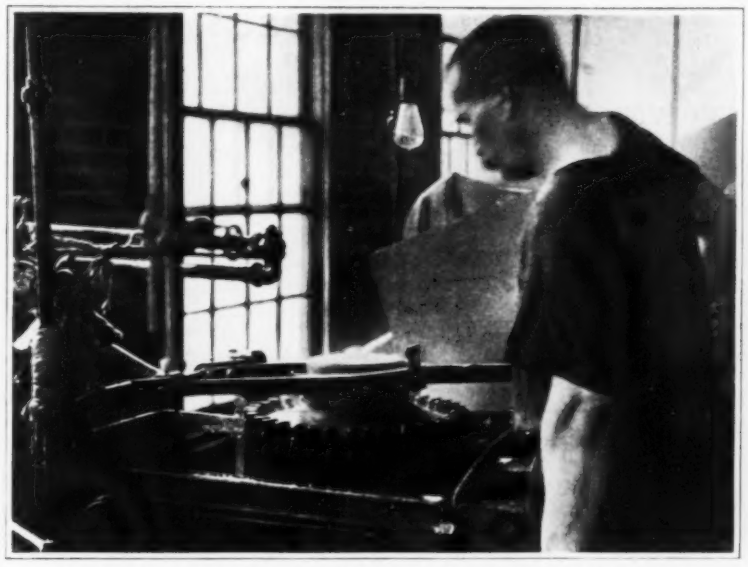
The cones are shrunk by passing between rolls that run in hot water



The final shrinking and felting of the cones requires careful and skilled manipulation

Photographs copyrighted, Brown & Dawson

This machine stretches and forms the shrunk cone to the proper shape for a hat

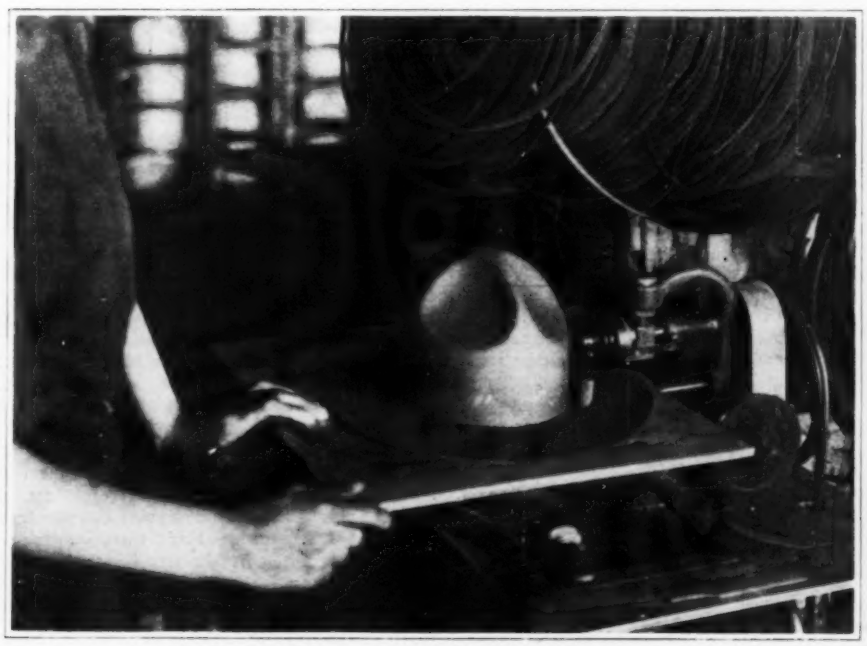


Another view of the forming machine. The fingers stretch the brim and the mold forms the crown

After forming, the hat is smoothed on an emery roll that trims off the rough spots

After being ground, the remaining loose hairs are singed off over an alcohol flame

One of the last processes is shaping the hat in a heated mold under pressure



Finally, the brim is smoothly cut to size and the trimmings are put on

Photographs copyrighted, Brown & Dawson

# The Treatment of Cases of Shell Shock*

## In an Advanced Neurological Centre

By William Brown, M.A., M.D. Oxon., D.Sc. Lond., Reader in Psychology in the University of London, King's College; O. C. Craiglockhart War Hospital

WHILE in charge of an advanced neurological centre in France during the period November, 1916—February, 1918, I have had to deal with between two and three thousand cases of psychoneurosis (neurasthenia, hysteria, and psychasthenia), and in the following paragraphs I will endeavor to give, in broad outline, a general view of the methods of treatment which have seemed to be most useful, and a statement of certain statistical results. The great majority of cases came under my care within 48 hours of their breakdown, and I was able to return 70 per cent. of them to the line after an average of a fortnight's rest and treatment in hospital; of course certain individual cases needed a longer rest in hospital, up to two or three months. I feel sure that this success was due more often to *prevention* than to cure. By seeing so many of these light cases so early I was able to *prevent* the development of further hysterical or pithiatic symptoms which would otherwise have taken place.

### ESSENTIAL FACTORS IN CAUSATION AND TREATMENT.

It is important that the patient should have the benefit of a thorough examination of his nervous system at the earliest posible moment after the shock of the shell explosion. The incipient functional symptoms from which he is suffering make him fear, vaguely or definitely, that he has sustained some organic injury of the nervous system. This fear encourages the further development of such symptoms. It and its effects can be brought to an end by the reassuring remarks of the neurologist, after he has completed his examination. But those remarks must be repeated and forced upon the patient's notice. Especially is it the note of certainty in the doctor's voice which carries conviction. By one means or another the patient must be completely convinced of the truth of the doctor's explanation of his symptoms, and of the promise that they will quickly disappear. This conviction must pass beyond the stage of mere intellectual awareness and acceptance, and acquire the dynamism of strong emotion. Enthusiastic expectation of a rapid recovery is another essential condition of success, just as it was an earlier apprehension which was responsible for the development of the symptoms.

This is more than mere suggestion and counter-suggestion. The mechanical processes of auto- and hetero-suggestion do certainly come into play in the *fixation* of the symptoms and in their later development and multiplication. But the *origin* of the symptoms (tremors, difficulties of speech and locomotion, profuse sweating, headaches, diminution or loss of various forms of sensation, &c.) is to be found in the intense emotion of fear caused by the shell explosion, of which they are the objective physical manifestations. In like manner, although counter-suggstion plays its part in the cure of these functional symptoms, the factors which are of very much greater efficacy and importance in bringing about a *permanent* cure are: (1) persuasion, whereby the patient is rationally convinced of the true nature of his symptoms; and (2) the sthenic emotions of confidence, conviction, and expectation, which have a unifying effect upon the mind, and counteract the disintegrating effect of mechanical suggestion.

It will thus be seen that I adhere to Déjerine's theory of the pathogeny of the psychoneuroses in preference to that of Babinski. As regards the "period of meditation" which often elapses between the occurrence of the emotional shock and the onset of the earliest symptoms, I would also follow Déjerinè in holding that it is a period of subconscious emotional development. Babinski and his followers believe that it is a period during which auto- and hetero-suggestion co-operate to bring about the ultimate outbreak of the symptoms. The original shock, no doubt, produces some weakening of mental synthesis, although outwardly the patient does not appear greatly disturbed. The appropriate emotional reaction, with its innervations and external manifestations, develops gradually during the following few hours or days, as the patient's intellectual awareness of the accident arouses by association earlier emotional memories. The symptoms that eventually arise are such emotional manifestations in a state of relative dissociation and permanence. As Déjerine says:

"Everything that an emotion may create in an accidental and transient way hysteria may accomplish in a lasting way."[1]

### CASE OF DELAYED ONSET OF SYMPTOMS.

I have several examples of this delayed onset of symptoms in the case of hysterical mutism and hysterical hemiplegia which I hope to analyse and describe on another occasion. But I have obtained the following unbiased introspective description from one of my officer patients who suffered from hysterical spasmodic contractions of the abdominal and leg muscles and profuse sweating and tachycardia, which came on some days after the time when he was exposed to heavy shelling. His account is as follows:

"My feelings during the shelling are hard to define, as I was too fully occupied to allow much thought on the subject. Owing to the small area to which we were confined, there was no opportunity of being able to give vent to the pent-up feelings that were in me, and in consequence my nerves were strung up to such a pitch that I felt that something in me would snap. Every shell fired seemed to be nearer the mark than the last, and the ground all around was covered with shell holes. The general feeling was that 'the next one' would land right in the post. Part of the trench had already been blown in. The back blast from each explosion flattened us up against the wall of the trench.

"The days following I was always thinking of this episode, and nights I could never sleep, but would just doze and then wake up with a start, with my heart palpitating furiously and with great difficulty in breathing. I would also find myself in a profuse cold sweat, especially of the scalp, forehead, and hands. Then my legs began to be affected and would shake as though I had the ague. This would come on in the day at times, but invariably happened at night when I was lying down. About ten days later I was troubled with my stomach [he means abdomen]; at night something—I suppose my nerves—started pulling me up forward as I lay down and my body shook all over. This would happen every two or three minutes. This action affected my back, and I had a belt of pain around me. During this time I was always troubled with my heart, and I found it hard to lie down at all. The cold sweats also continued."

### EMOTIONAL ORIGIN OF THE SYMPTOMS.

This description, written by an officer unversed in psychology and quite ignorant of the question at issue, is in favor of the emotional origin of the symptoms, although, of course, factors of suggestion are not entirely absent. The emotion of fear in this patient during civil life always produced cold sweats, palpitations, and tremors of the limbs—just as in the case of a patient subsequently suffering from functional paraplegia it used to "take him in the legs" and he would feel weak at the knees. The period of incubation in some cases seems to correspond to the time during which the patient is struggling, with a certain degree of success, to repress the painful emotional memories and to remain "captain of his soul." The final outbreak of the symptoms represents the partial failure of this effort of repression, or rather is a condition of the success of the *psychological* repression. The symptoms are "convertion" symptoms, in Freud's sense of the term—i. e., they represent painful emotion converted into physical innervations.

With a certain class of patients, a more detailed form of mental analysis is necessary. In these cases the nervous breakdown is partly due to earlier mental worry, and the "active service" element is simply the last straw. The patient's mind is a battlefield of conflicting emotional tendencies, many of which he himself fails to recognise. By long talks with him, following up thread after thread in the association of his ideas, one can recall repressed memories of earlier epochs in his life, showing him the true emotional significance of them and their connexion with his present disability. In this way the patient learns to understand himself, and therefore I would call the method "*autognosis*." Self-knowledge brings with it self-control in the psychic domain. An analysis of the patient's dreams is often of the greatest help in this method. Indeed, the dreams of some of these patients are so terrifying that they have to be dealt with, and the quickest way to exorcise them is to analyse them—i. e., to trace the different parts of the dream back to their source in the patient's earlier life (by the method of "free" association), and so to discover the underlying unconscious dream thoughts which have been enjoying a disguised or distorted fulfilment in the dream itself.

### TREATMENT.

I now come to a therapeutic method which I have found to be especially valuable in dealing with *early* cases of shell shock exhibiting pronounced symptoms of functional nervous disorder, such as functional mutism, deafness, paralysis, tremulousness, &c., accompanied by more or less extensive amnesia. It is a form of hypnosis, but free from the defects attaching to the ordinary use of that method. To explain by an example:

Here is a patient who was blown up and buried by a shell explosion two days ago and lost consciousness. On regaining consciousness some hours later he found that he was quite dumb, and also had lost all recollection of the shell explosion and of the events immediately following thereon. In other words, he is functionally mute and has retrograde amnesia. His memory for other recent experiences is also vague, but he is in full command of gesture-language and can write down on paper all that he wishes to say.

I interview him alone in my office and tell him in a tone of conviction that I shall restore his speech to him within a few minutes if he will do exactly what I say. I then tell him to lie down on a couch, close his eyes, and think of sleep. I urge him *to give himself up to sleep*, to let sleep come to him, as it assuredly will. I tell him that he is getting drowsy, his limbs are getting heavy with sleep, all his muscles are relaxed, he is breathing more and more slowly, more and more deeply. Above all, that his eyelids are getting heavy, as heavy as lead, that he feels disinclined to open them, that he cannot open them however hard he tries. At this stage, which generally supervenes within two or three minutes, he really cannot open his eyes. This is a stage of very light hypnosis quite sufficient for my purpose.

I now tell him that the moment I put my hand upon his forehead he will seem to be back again in the trenches, in the firing line, in the fighting, as the case may be, and will live again through the experiences that he had when the shock occurred. This I say in a tone of absolute conviction, as if there is not the slightest shadow of possibility of my words not coming true. I then place my hand on his forehead. He immediately begins to twist and turn on the couch and shouts out in a terror-stricken voice. He talks as he talked at the time when the shock occurred to him. He really does live again through the experiences of that awful time. Sometimes he speaks as if in a dialogue, punctuated with intervals of silence corresponding to the remarks of his interlocutor, like a person speaking at the telephone. At other times he indulges in imprecations and soliloquy. In some cases he is able to reply to my questions and give an account of his experiences. In others he cannot do so, but continues to writhe and talk as if he were still in the throes of the actual experience. *In every case he speaks and acts as if he were again under the influence of the terrifying emotion.* It is as if this emotion had been originally repressed, and the power of speech with it and is now being worked off and worked out.

### ABREACTION.

This process of "working off" repressed emotion is what Freud calls "abreaction." In my view it is the essential therapeutic process in dealing with the majority of war psychoneuroses. The original shock caused a *dissociation* of consciousness—i. e., an apparent suppression of a certain series of memories and of a certain motor function (speech). Now, without accepting Freud's sexual theory of the origin of the psychoneuroses, for which I have never been able to find any convincing evidence (i. e., as a universal pathogenic factor), I *do* accept his theory of the cause of mental dissociation—viz., that it is the result of mental conflict and involves repression of emotional states. The repression of any emotion at its inception involves

*From *The Lancet*.

[1] Psychoneuroses and Psychotherapy, pp. 269, 270.

the danger of dissociation, the ideas accompanying the emotion being then more ready to split off from the rest of the mind and pursue a subconscious life of their own.

In most cases of nervous shock caused by shell explosion a state of intense fear is aroused in the patient's mind, which, from its very magnitude, produces loss of self-control and apparent loss of consciousness. There is no real loss of consciousness, but the attempted repression and control of the fearful emotion at its inception brings about a splitting of the mind, which appears later as an amnesia of greater or less extent, often involving other losses of function also, such as dumbness, deafness, tremulousness, or paralysis. The fact that under light hypnosis, and with the appropriate suggestions, these memories return, together with the lost voice, hearing, &c., is evidence that they were not abolished at the time, but were simply split off from the main personality. It is also evidence that the shock worked mentally rather than by its accompanying *physical* concussion (which is often absent).

In my method, then, the patient goes through his original terrifying experiences again, his memories recurring with hallucinatory vividness. It is this which brings about the return of his powers of speech, and not direct suggestion, as in the ordinary method of hypnosis.

My second modification of the ordinary method is in my manner of awakening the patient. Remembering that his disability is due to a form of dissociation and that in some cases hypnotism accentuates this dissociation, I always suggest at the end of the hypnotic sleep that he will remember clearly all that has happened to him in this sleep. More than this, I wake him very gradually, talking to him all the time and getting him to answer, passing backwards and forwards from the events of his sleep to the events in the ward, the personalities of the sister, orderly, doctor, and patients—i. e., all the time re-associating or re-synthetising the train of his memories and interests.

By the process of *abreaction* I remove the underlying *cause* of the patient's original dissociation, and in attacking this cause I cannot be accused of merely treating symptoms.

I agree entirely with Pierre Janet that only hysterical patients can be hypnotised—in fact that, as Charcot and said many years ago, "hypnosis is an artificial hysteria." It follows from this that as the patient improves under treatment he should become less and less hypnotisable. This is the case with my form of the method. Hypnotism has been brought into disrepute by those seekers after the marvellous who have intentionally split up the personality of their subjects more and more in order to get ever more wonderful and abnormal manifestations from them.

Using this modified form of the hypnotic method, one can abolish that tendency towards "*equivalents*" which Janet mentions as one of the three stigmata of hysteria (the other two being *suggestivity* and *distractivity*). By this is meant the tendency which the patient shows to suffer from another functional symptom as soon as his original symptom is removed by suggestion under hypnosis. For example, a mute may develop headaches or gastric symptoms as soon as he has been made to speak by suggestion under hypnosis. By using "abreaction" this tendency is completely eliminated. The use of suggestion *without* hypnosis quite fails to remove this tendency to develop equivalent symptoms. The equivalent symptoms are often so vague that they are not noticed at the time, although they are none the less disabling.

### RESULTS OF TREATMENT.

The hypnotic method is needed only for the very small minority of cases that arrive at an advanced neurological centre—only for those showing so-called major hysterical symptoms. In two series of 1,000 cases each I treated 173, or 17.3 per cent., in the first, and 132, or 13.2 per cent., in the second by means of hypnosis. In these two series there were altogether 121 cases of loss of speech, or hysterical mutism. I succeeded in curing *every single one of these cases.* Many of them were deaf as well as dumb. These were given a paper of instructions to read, in which they were told to lie down, close their eyes, and give themselves up to sleep. When such a patient showed by the calm look on his face that he had reached a quiet frame of mind, I would suddenly and unexpectedly bang two books together near him, and have the pleasure of seeing his eyes flicker, and then find that he could hear. I could then continue the treatment by word of mouth in the ordinary way. Curiously enough, these deaf-mutes were the easiest of all my cases to treat.

Of course, there are some patients who are ready to malinger with major hysterical symptoms. I caught out 28 such patients in my first series of 1,000 cases, and induced them to confess. But this is, happily a very small proportion—less than 3 per cent.

If, finally, the modified hypnotic method is limited in application, wherever possible, to *one* treatment only all the drawbacks with which the ordinary hypnotic method is beset are evaded. I only applied the method to the more severe cases, those that had later to be evacuated to the base.

Nevertheless, in such apparently severe cases as those of functional paraplegia this method was not found to be necessary. Vigorous persuasiveness was sufficient to produce a cure. In some of the lighter cases of mutism also this was found sufficient.

*Stammering* is much more difficult to cure than mutism. The patient can more easily cling to the first symptom than to the second, and every hysteric clings to his symptoms. But in several cases I have produced a complete cure, and a decided improvement in others. In several cases where the patient had stammered in civil life I was able to trace the stammer back to a shock in early life, in the first few years of childhood, and under hypnosis I was able to call up the experiences with hallucinatory vividness before the patient's mind. The stammering was not completely cured thereby, because it had become the habit of a lifetime, but this recall of the shock was the first necessary step towards a cure.

### ANOTHER ILLUSTRATIVE CASE.

As a further illustration of my method I will describe the case of an officer, aged 25 years, whom I treated in France in December, 1916, and whom I happened to have again under my care at Craiglockhart in May, 1918.

He had been sent into my neurological wards on account of his complete inability to stand shell fire, having the irresistible impulse to rush to his dugout and crouch down there the moment shells began to fall in his neighborhood. Earlier in the year (1916) he had been wounded during an advance and had been left out in No Man's Land under continuous shell fire for several hours. He gave a history of great timorousness and extreme weakness of memory during his youth. I learnt from him that he had been nearly drowned at the age of 3 years, according to what his mother had told him. He himself, of course, could remember nothing of the incident. I should also add that he exhibited many psychasthenic symptoms—e. g., he would begin to count the squares round the top of the stove in his ward, and find that he could not stop counting them. He would be impelled to count them hundreds of times.

I hypnotised this officer and then directed his attention back to the drowning incident at the age of 3 years. He at once began to live again through this incident, gasping with terror as he again, in memory, fell into the water. He described the whole event with such a wealth of detail that it was difficult not to believe that he had been taken straight back to this early period in his life and was living again through the terrifying experience. Later on, he re-experienced with hallucinatory vividness the incident of his baby brother's funeral, seeing again the coffin being lowered into the grave and feeling the desperation of grief *as a present emotion.* He was 18 years old when this funeral took place.

I concluded from these and other results of the hypnosis that the patient's memory was intact, but that certain factors were interfering with the power of recall—viz., the very strong emotional tone of many of these memories, combined with repression of them following upon mental conflict. The "abreaction" of these painful memories in the hypnotic state—i. e., the working off of their emotional accompaniments—should therefore prove beneficial to the patient's powers of memory and to his general mental condition. This was found to be the case, and the patient appeared quite a different, and certainly a much more normal, person after the treatment.

A minor point of interest arising out of this case is that the patient was readily hypnotised in spite of his psychasthenic symptoms. Some authorities have held that psychasthenics are not hypnotisable.

In May of this year I learn from this patient that his mother vouches for the accuracy of his revived memories of the drowning incident in every particular. He is again in hospital suffering from certain neurasthenic symptoms, but he has completely recovered from his previous hysteria. He has done a year's duty since he was with me in France.

### OTHER TREATMENT.

General hygienic measures are, of course, necessary in the after-care of severe cases, and suffice for the entire treatment of the largely preponderating light cases. Regularity is insisted upon in all habits, alimentation, excretion, sleep, exercise. The patients are put on physical drill and sent for short route marches. Many do light duty in the wards or in the grounds of the hospital. But to the "gospel of work" is added the gospel of cheerfulness and hope.

For insomnia suggestion treatment at night is often very efficacious. The patient can often be soothed to sleep and incidentally taught how to employ auto-suggestion in this case.

Only very rarely have I found it needful to *isolate* patients. But this device succeeded in the case of three patients showing persistent tremors of the head, where every other method had failed.

### SUMMARY.

The essential therapeutic agent in the case of *hysteria* caused by shell shock is "abreaction," or the working off of the repressed emotion caused by the shock. Mental analysis is a means to this end, and light hypnosis, applied under proper safeguards, is the quickest and most effective method of effecting this analysis, where amnesia is present and the case is seen early.

For cases of *neurasthenia*, which are the more numerous and involve emotional preoccupation often dating back many years, mental analysis and re-education, without hypnosis in any form, are the needful agents, although the abreaction of the original emotional disturbance or disturbances is again essential.

In both classes of cases the arousing of *sthenic emotion* in the patient's mind is an important adjunct in the cure, both in the form of enthusiastic confidence in his doctor and expectation of a complete recovery, and also in the form of vivid interest in some form of occupation in the stage of convalescence, during which the mind becomes more unified and consolidated.

I have hitherto not mentioned *rest*, which is, of course, also fundamental. But no complete rest is possible while the mind is obsessed with bottled-up emotion. This emotion must be completely worked off, and then true rest will come. The preoccupations of the neurasthenic also must first be dealt with if any form of rest cure is to produce good results.

After three and a half years of work with nerve patients in military hospitals in Egypt, England, and France, during which over 4,000 cases have passed through my hands, I feel no hesitation in saying that mental analysis is the ideal method of treatment, provided that it is carried far enough to produce true abreaction of emotional states. As an aid, and as a sort of short cut, the special form of hypnosis which I have described is very useful in early cases showing major hysterical symptoms.

## Synthetic Rubber

At a recent meeting of the German Bunsen Society held at Berlin, the question of synthetic rubber was discussed and its possibilities as a substitute for the natural product were considered. The world's requirements before the war amounted annually to some 145,000 tons. Since 1914, however, the demand apart from the needs of the Central Powers has increased to 220,000 tons. Of this quantity America takes the greater part. In the period 1910-12, according to the *Chem. Trade Journal*, 63 (1918), 162, attempts were made by Frantz Hoffman at Leverkusen to produce a substitute by synthetic processes. These were in large measure successful but the constant fall in prices of the natural product resulted in the partial abandonment of the experiments. The enormous demand brought about by war conditions and the shortage in Germany and Austria have given fresh impulse to this promising new branch of industry. In spite of the difficulty of obtaining materials 150,000 kilos of methyl rubber are produced monthly. It was not at first a wholly satisfactory substitute, for it became oxidized in air and was somewhat refractory in the process of vulcanization. These objectionable qualities have, however, been in large part removed by improvements in manufacture. By the addition of other substitutes a useful hard rubber, it is said, is now produced, equal in firmness and durability to the natural product, and 20 per cent better for electrical insulating purposes. The accumulator boxes used in submarines are made of this hard rubber. Soft rubber is more difficult to make. At ordinary temperatures the product is not elastic but leatherlike. It becomes elastic as its temperature is raised. The addition of dimethyl aniline and toluidine increases the elasticity of the manufactured material. It is now used for tires for heavy road motors. A factory of large extent has been built at Leverkusen, capable of producing 2,000 tons annually.—*Jour. Ind. and Eng. Chem.*

# Ignition Magneto Construction*

## Some Points on Design, Magneto Magnetizing and Testing

By H. R. Van Deventer[1]

Most magneto troubles in the field are due to mechanical defects rather than to electrical faults or features of design. Magnetos of widely different types and constructions may prove equally effective so far as producing a spark is concerned, but on account of mechanical defects one type or make may give continued service for years while another will fail after a few weeks of service. The paper reviews briefly certain features of magneto construction and adjustment.

Magnetos may be roughly divided into two types, low-tension, as used on engines having make-and-break igniters, and high-tension or jump-spark types, as used on engines having spark-plugs. The low-tension types are seldom used on engines having more than one cylinder, while high-tension magnetos are used on engines having one or any number of cylinders, and with these cylinders arranged at various angles.

### MAGNETO CONSTRUCTION.

To meet the requirements of internal combustion engines magnetos must be of many sizes and types. This should be kept in mind when considering the following data which are of necessity general in character. There are certain points necessary from a mechanical point of view that must be given careful consideration in any magneto, whether it is intended for use on a stationary farm engine infrequently run and making a few hundred revolutions per minute, or in battle airplanes running for hours at high speed. In addition to these general requirements each size and type of magneto has certain mechanical details worthy of careful study. These details, however, it is impossible to cover in a paper of this character.

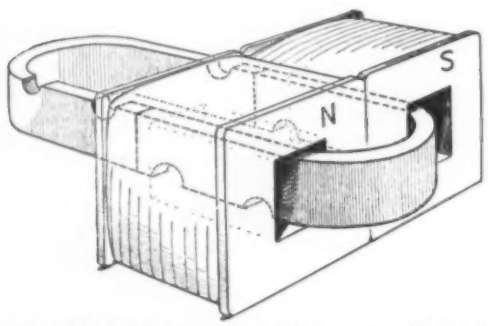



**Fig. 2. Method of inserting magnet in magnetizing coil**

All magnetos have magnets. Prior to the war, steel containing 5 per cent. tungsten was used, but during the past two years chromium steel has been used with entirely satisfactory results as far as the life and efficiency of the magnets are concerned. The chromium steel is somewhat harder to work than tungsten steel.

The purchaser must take the magneto manufacturer's statements as to the tempering and magnetizing, and can do little more than inspect the magnets for workmanship, see that they are properly formed and ground to fit the pole pieces of the magneto, and that the grinding has not drawn the temper.

In the majority of low-tension magnetos the magnets are attached to the pole pieces by screws, and it is preferable that some means be employed to seal at least one of these screws so that the magnet cannot be removed from the magneto without breaking the seal, thereby showing when the magneto has been tampered with.

Magneto manufacturers know that in the majority of cases where magnets are reported dead, 99 per cent. of the trouble is due to the battery having been connected to the magneto, thereby demagnetizing the magnets. Other troubles are caused by taking the magnets off the magneto without applying a keeper, or by replacing them wrongly.

### METHOD OF MAGNETIZING.

While methods of magnetizing do not come within the scope of this paper, it is thought that the latest practice in this connection will be of interest. Fig. 1 shows a magnetizing coil with the master magnet in place. These coils are supplied by the magneto manufacturer and are designed for various voltages, usually 110 volts, direct current being used in all cases.

The coils are connected up and so marked that the N and S poles are known, and all magnets of a certain make of magneto should be magnetized in the same direction. The magnet to be magnetized should be connected to the one in the coil and pushed forward so that it is covered by the coils, as shown in Fig. 2. The switch connecting the coils to the source of current should then be thrown in one second and opened while the magnet being magnetized is in the coils, as shown. After the switch is opened the magnet being magnetized should be pulled forward, and, before separating it from the one in the coil, a keeper should be placed across its poles, as shown in Fig. 3. This keeper should not be removed until the magnet is in its position on the magneto, as shown in Fig. 4. It will be found that magnets properly magnetized and not subjected to any mechanical abuse will retain their strength indefinitely unless the battery current is pased through the windings of the magneto.

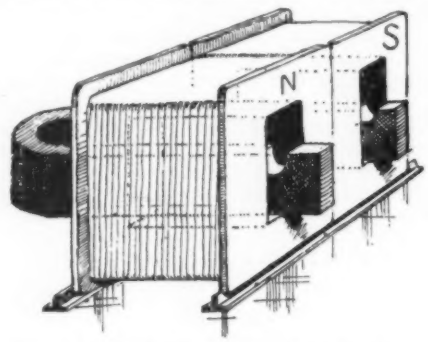



**Fig. 1. Magnetizing coil and master magnet**

### MAGNETO DESIGN.

The question of design of the magnet proper is of considerable importance to the purchaser. As a general rule magnets having a considerable distance between their poles are more liable to short life than magnets in which the poles are closer together. Practically all modern makes of magnetos of the rotary high and low-tension types have well-proportioned magnets.

The magneto manufacturer must secure the proper grade of iron and treat it properly or it will not be electrically efficient. The purchaser should note, however, that the air gap between the armature or rotor and pole pieces, is as close as is consistent with good mechanical practice, and that the construction of the armature or rotor and its bearings is such that this air gap will be maintained at all speeds and during the life of the magneto.

### TYPES OF BEARINGS.

The magneto bearings are divided into two classes, plain and ball. Plain bearing magnetos are usually those of the low-tension variety, although there are several models of plain bearing high-tension machines recommended for stationary engines of ordinary speeds, as there is no need of putting in expensive ball bearings where they are not required.

The life of the plain bearing machine seems to be entirely dependent on the treatment the magneto receives; the purchaser should see that the oil holes are provided with suitable covers; and the best low-tension models are equipped with oil pots adapted to hold non-fluid oil, so that when once filled the magneto will run several months without attention. Wick oilers are used on the larger models and afford efficient and reliable means of lubrication. Lack of oil will cause the magneto shaft to stick and break.

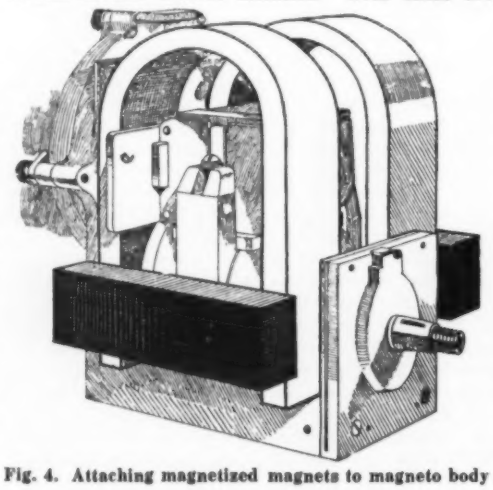


**Fig. 4. Attaching magnetized magnets to magneto body**

Practically all magnetos for high-speed engines such as aeronautic and automobile are equipped with ball bearings. In some cases ball-bearing distributors are used. The usual methods of oiling are employed on most models. In some magnetos for relatively slow-speed work the bearings are packed with grease and put into the magneto and no provision is made for ever oiling them again. It is found that such bearings will give good service when properly protected from dirt.

Shuttle-type armatures have a clearance of about 0.005 in. The annular bearings are subject to wear from the following causes:

A broken ball will cut the ball races and in turn cause the armature to rub against the pole pieces. Lack of lubrication in either of the bearings will cause them to become cut and roughened, a new bearing being the only remedy. The grounded brush may be missing or dirty, causing the ball bearings to become pitted and rough. The back plate screws may become loose from excessive vibration, causing the armature to stick, with a resultant breaking of the drive shaft. The coupling may not be flexible and will cause the bearings to wear sideways; the armature will rub on one end. This may also occur if the magneto is too much out of line. The bottom bolts may be drawn up too tight, causing the case plate to spring, with the result that the bearings are run tight and thus ruined. The twisting of the armature out of line may cause the winding to rub and chafe, grounding the winding. The four screws holding the armature heads may become loose or shear from the twisting strain and wreck the armature. The drive shaft may become loose, due to tight bearings or too great magnetic pull, or to faulty construction, especially if the drive end is made from other material than manganese bronze.

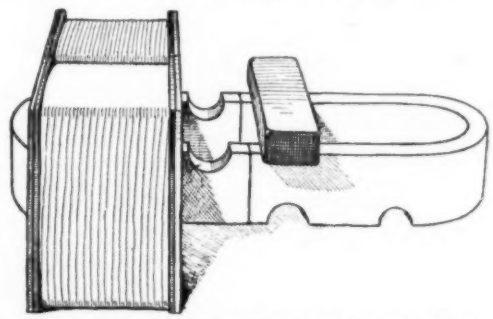


**Fig. 3. Before removing magnet, a keeper is placed across the poles**

In the case of high-tension machines of the armature type the customer can do little more than inspect the armature for general workmanlike appearance. In magnetos of the stationary coil type, the coil can be inspected.

The windings on modern magnetos give little trouble if properly manufactured. The purchaser of low-tension models should take several of the samples submitted and have the armatures unwound to see that the winding is laid on in smooth layers and properly insulated from the armature core. When armatures are loosely wound the wire may slip, thereby causing short-circuits or binding of the armature.

### TESTING MAGNETOS.

In inspecting the windings and small insulating parts of magnetos through which high-tension current is conducted, a testing outfit, shown in Fig. 5, is of considerable value. A twelve-volt battery is used. Operating switch *A*, when closed, completes the battery circuit through the vibrator. The safety gap is set at 7/16 in. In testing out a part which carries high-tension current, for instance a spark-plug cable, connect the wire *M* to the wire of the cable and pass the wire *L* along the outside over the exterior surface of the rubber. Any rupture is very easily found in this way. The same rule also applies to testing leaks in distributor spools, such as that shown in Fig. 6, one wire being connected to the brass segment and the other passed all about the insulation surrounding the segment. This is really nothing more than a mechanical test, as any crack in one of these spools will render it useless. Trouble here is often due to the surface on which the brush bears becoming rough. It should be smooth.

*An abstract from a paper in *The Journal of the Soc. of Automotive Engineers.*

[1]Splitdorf Electric Company, Newark, N. J.

BREAKER DESIGN.

The interrupter mechanism or as it is commonly called, the breaker, is usually mounted about the end of the magneto shaft and consists of a movable contact member adapted to open and close the primary circuit of the magneto. This interruption may take place once per revolution, or a number of times per revolution, depending upon the number of cylinders the magneto is designed for and the shape of the cam. It is very essential that the points separate when the rotor or armature is in a certain position in relation to the pole pieces. This will be clear from a reference to Fig. 7 in which the gap between the edge of the rotor and the pole *H* is shown.

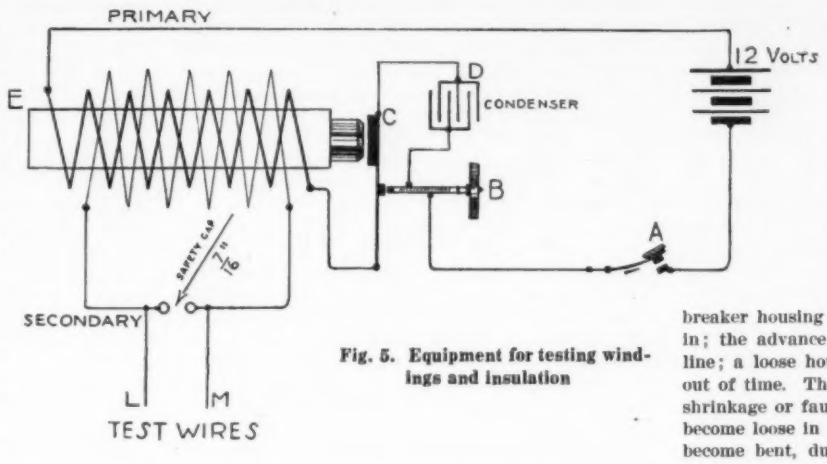



Fig. 5. Equipment for testing windings and insulation

It is difficult to judge just when the contact points in a breaker open, as a movement of even as little as 0.01 in. which the eye cannot see, breaks the circuit; it is well to use a test buzzer, shown in Fig. 8. The magneto shaft is rotated as indicated by the arrow on the oil cap, which shows the running direction of the magneto. While the contact points are closed the buzzer circuit is closed, and the buzzer will operate until the contact points open. Just at that instant, when the buzzer ceases to operate, stop turning the magneto shaft and use a thickness gage, as shown, to measure the gap *X*. There is no adjustment more essential than this one if the most effective performance of the magnet is to be secured, and it is obvious that only through correct mechanical work can this accurate adjustment be obtained.

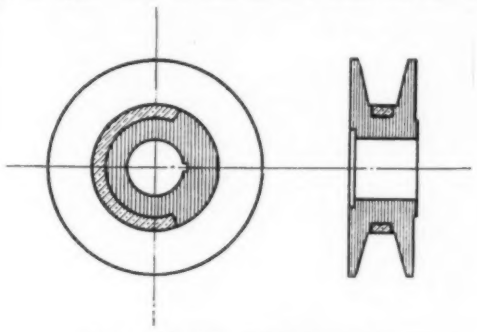


Fig. 6. Magneto distributor spool

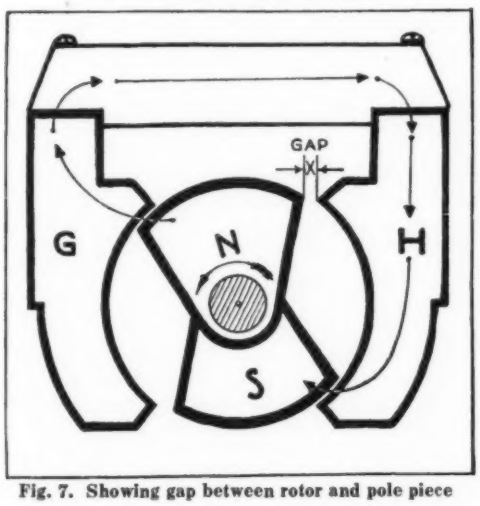



Fig. 7. Showing gap between rotor and pole piece

Fig. 9 shows another important part, the breaker arm or lever, common to all magnetos. It is seldom that the platinum points will be found defective. Sparking at the points is usually due to oil, misadjustment or a defective condenser. The main thing is to see that the points are clean and not loose.

The fiber bumper may become loose in the breaker arm, and purchasers should examine this part very carefully to ascertain how the bumper is secured in place and if it can be removed in case of wear. New bumpers should always be filed to fit the cam. That edge which the cam first comes in contact with should be filed until the contact points separate, when the gap between the rotor and pole pieces is in accordance with the limits given by the manufacturer. The breaker construction must be such that the breaker bar cannot become tight on its stud and thereby stick in the open position. Sometimes this occurs because of insufficient lubrication. Some magnetos have the breaker bar mounted on a hollow pin, which communicates with an oil hole in the edge of the breaker box, through which oil may be applied.

Breaker boxes on most magnetos are movable for advancing and retarding the spark, and on machines where the breaker box *only* is moved, attention should be paid to the way the box is secured, so that it will move easily without binding and at the same time not wobble about the cam. In the stationary-coil type the breaker box is secured to and moves with the field structure and therefore sticking is impossible. This feature also makes it possible to secure the same degree of spark intensity with the magneto, either full advance or full retard, as the relation of the gap *X*, Fig. 7, to the time of opening of the points is always the same regardless of the advance or retard position.

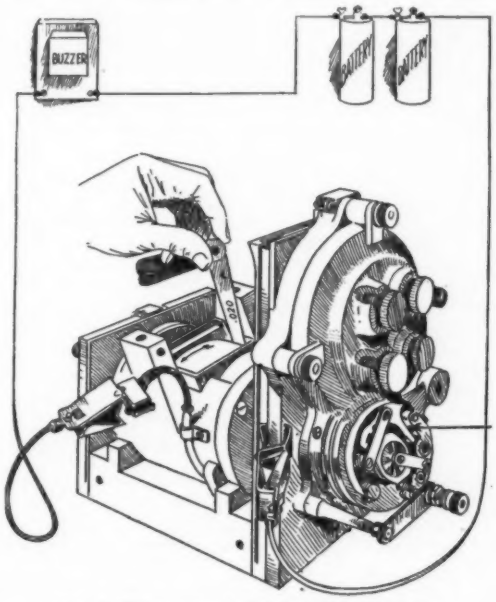



Fig. 8. Buzzer employed for setting breaker contact parts

The troubles arising from mechanical defects in circuit breakers are numerous and may be caused by the following:

Insufficient lubrication of the breaker lever, causing it to stick and corrode. A loose breaker-bar bearing stud, due to faulty riveting. Breaker bar bearing stud too small in diameter, causing undue wear in the breaker lever bearing. Breaker bearing stud too large in diameter, causing breaker lever to stick. Breaker-bar bearing stud or breaker lever wearing, due to electrolysis. Undue fiber bumper wear, the cams being too abrupt or too rough. Breaker lever too heavy or out of proportion, causing the bearing to wear rapidly. A breaker lever spring that is too stiff, causing the bearing and contact points to wear. Rapid fiber cam wear, due to dust entering the breaker housing. In a revolving breaker the breaker lever bearings are sometimes made of fiber, which will cause the breaker lever to stick under atmospheric changes. The insulating bushings of the contact screw bracket on a revolving breaker become cracked from heat, causing these parts to loosen. Breakers that revolve left-hand and have a right-hand screw or threaded bolt to hold them in place often become loose and are broken, or fall off and become lost. The greatest wear is usually in the breaker housing bearing, caused by road dust working in; the advance lever rod may be too stiff or out of line; a loose housing will cause the contacts to break out of time. The fiber bumper may become loose from shrinkage or faulty fastening. The contact points may become loose in breaker bars, or the breaker bars may become bent, due to light construction. The breaker bar may become crystalized and break. The ground connection of the breaker bar may be poor. Revolving breakers may become loose and turn, destroying the relation of the circuit breaker to the magnetic break. A breaker base fastening screw may be too long, puncturing the condenser or breaking the screw off.

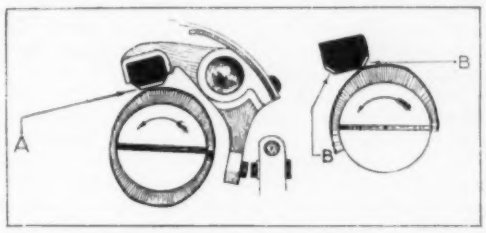



Fig. 9. Breaker arm or lever

Breaker fastening screws that are too large in the thread cut like a tap and fill up the inner end of the breaker sleeve with brass chips, short-circuiting it.

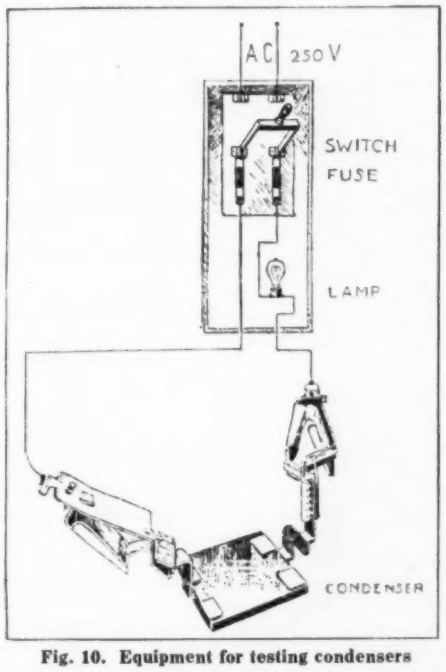



Fig. 10. Equipment for testing condensers

Revolving breakers not running true will cause incorrect breaking of the contacts and wear the cams.

MICA CONDENSERS.

The purchaser can do little toward satisfying himself as to the quality of mica condensers. This is a matter which concerns the manufacturer. Fig. 10, however, shows how the condensers can be tested electrically. There should be no electric current through the condenser when the switch is closed and therefore the lamp should not light. If the lamp does light the condenser is defective. Condenser trouble is rare in modern magnetos, and manifests itself in flashing at the points and failure of the spark.

Fig. 11. Correct length of contact segment of distributor disk (right-hand diagram). Other diagrams are incorrect

Fig. 12. "Retard" position of contact distributor at A, and "Advance" position at B

DISTRIBUTOR DESIGN.

The distributor whereby the spark produced by the magneto is led to the several cylinders should receive careful attention, for here mechanical defects are often found. In the first place

the material in a distributor should be of high insulating quality, should be impervious to moisture, readily cleaned and not affected by heat. It should also be mechanically strong to withstand the abuse to which it is often subjected.

No attempt will be made here to discuss the relative merits of distributors having a single traveling brush as compared with those in which there is one brush for each cylinder and a single traveling contact; nor will the gap type of distributor in which a rotating finger passes near a terminal for each cylinder, a gap intervening, be discussed, as such arrangements merely sidestep the distributor problem. An actual contact is necessary, and while gap distributors eliminate brush trouble, they introduce other much greater evils.

The various parts of the distributor should be inspected by the customer to determine whether or not they are properly proportioned. For instance, the length of the contact segment in the distributor disk is a matter of vital importance, and some manufacturers in their endeavor to offer a distributor having a very limited amount of travel, or to squeeze a twelve-cylinder distributor into very small limits, have shortened up the contact segments. Why this should not be done, will be evident by referring to Fig. 11, which also shows the results of a wrong setting or meshing of a distributor gear on the rotor shaft. The left-hand figure and also the middle view show what happens when the gear is improperly meshed, while the view at the right shows the proper setting. Suppose the manufacturer has used a short segment. The retard position of the contact distributor is shown at *A* (Fig. 12) and the advance position at *B*. Suppose the segment to be only half the length shown in the figure. It will be seen that the brush would run off the segment when advanced, which actually occurs in some magnetos.

Distributor bearings of the ballbearing type usually become defective from improper adjustment and the shock of the armature flux reversal. Wear on bronze distributor bearings is usually caused by poor lubrication and the accumulation of dust from carbon brushes, also by clogging of the oil duct leading to the distributor bearing and the dirt in the oil cup, which finds its way into the bearing when the magneto is oiled. Insulated distributor parts out of balance may cause the bearing to wear oval. Too much tension on the thrust button spring causes excessive end-thrust on the bearing, resulting in heating and sticking. Bearings of a graphite material or oilless bearings have been tried with poor results, owing to the softness of the bearing material; they are also very noisy. Adjustable distributor bearing plates may become loose, causing bearing wear from too much back-lash, or too tight meshing of the gears. Distributor shafts that are hollow and carry fiber or hard-rubber secondary connections may have these parts out of line or sprung, causing wear in the bearing. An unusual amount of wear may result from the rough surface of an unfinished distributor shaft when plain bronze bearings are used. Plain bearings composed of other metal than bearing bronze wear rapidly and become noisy and chatter.

### TESTS FOR MECHANICAL DEFECTS.

Mechanical defects are usually found on inspection by a competent person. In low-tension models they consist for the most part of broken and bent shafts, cracked magnets and stripped threads in the bolt holes of the case. In addition to these, high-tension machines show cracked or loose distributors, breakers loose or out of adjustment, distributor fingers or brushes missing or broken.

No test will equal that of actual service. The manufacturer, however, uses certain mechanical tests; for low-tension magnetos, these usually consist of short-circuiting the magneto and running it for several hours at a speed of 400 to 500 r.p.m. This initial short-circuit will decrease the magnetic flux of the machine as far as it will ever be, and any tight bearings or other mechanical defects usually develop during the run. The magneto is then taken off and tested electrically, and is finally connected up to a make-and-break igniter and the spark observed visually.

The testing of a high-tension magneto is somewhat more difficult. One four-cylinder machine is first oiled and the distributor wires are connected to individual spark-plugs having a 3/16 in. gap. Then the magneto is run 40 min. at 1,500 r.p.m., with timing lever full advance, and 10 min. at 3,500 r.p.m., full advance, and 10 min. at 150 r.p.m., noting that it runs equally well during the last test in either advance or retard position.

During these runs the contact points should not spark or flame excessively. There should be no excessive noise or stray sparks detected about the magneto. The safety gap in the magneto should be 5/16 in. and should not spark at any of the speeds given. See that the shaft of the magneto turns freely at the end of the test, making sure to distinguish the magnetic pull from any binding of the rotor. Examine the breaker bar to see that it moves freely. See that the platinum points come together squarely, line up, and are free from burning or blackening. Check up the opening of the points and see that it is as specified by the manufacturer. See that the bumper is running evenly over the surface of the cam and that excessive wear is not noticeable on either cam or bumper. Make sure that the distributor gear turns freely and that the oil feeds in through the cup, reaching the bearing properly. Examine the distributor disk to see that there is no heavy carbon deposit and that brushes are running evenly over the surface of the disk. Reject the magnetos in which carbon brushes run only on one side and reject any magneto which fails on the above requirements or in which any part not mentioned shows excessive wear. The mechanical tests for one twelve-cylinder magneto are practically the same as those mentioned above, except it is first driven 40 min. at 3,500 r.p.m., 10 min. at 4,500 r.p.m., and 10 min. additional at 150 r.p.m. In addition to the foregoing running tests, the following is a sample of the general inspection to which the magneto should be subjected, this applying particularly to the four and six-cylinder magnetos. Observe the general appearance of the magneto exterior finish, marking of rotation, fitting of covers, breaker box, etc. See that the rotation and advance lever or any special features correspond with the customer's specifications. Check taper of shaft and location and size of keyway. See that the holes in the base conform to specifications as regards size and location, and that they are tapped perpendicular to the plane of the base. See that all screws and nuts are tight and lock washers in place and that no screws are missing from the breaker box. See that the breaker arm moves freely, that the platinum points line up and that the breaker arm does not strike the cam at any other point than the bumper. See that the end play in the field structure does not exceed 0.004 in. The advance lever should move freely and should not rquire more than three pounds suspended from the hole in the lever to advance or retard it fully. Try the carbon brush springs to see that the pressure is light. See that the breaker cover spring fits tightly.

In conclusion, the statement made in the first part of this paper may be reiterated. Mechanical defects and the failures due thereto form by far the largest part of magneto troubles.

The magneto manufacturer has been "up against" many difficult problems, not only in meeting requirements which have ranged all the way from a magneto for a sixteen-cylinder engine, this magneto producing two sparks for each cylinder (which would mean a 32-point distributor), to a good high-tension magneto for a farm engine, to cost about $3.50. Limitations both in dimensions and weight have been met. All things considered, the magneto is truly a wonderful piece of equipment.

# Meteorology in Relation to Aeronautics—II*

## A Review of the Data Required by an Aviator When in the Air

By W. H. Dines, F.R.Met.S., F.R.S., Fellow

[Concluded from Scientific American Supplement, No. 2239, Page 352, November 30, 1918]

### THE WIND.

It will be well to separate the effect of the wind upon an aeroplane into two separate parts and then to discuss the present possibilities of foretelling what wind is likely to be found at any given height. The wind is decidedly the most important element with which an airman has to deal.

The first point to be considered is the gustiness, but this is a matter on which the meteorologist cannot give much information, he looks rather to receive information from those engaged in the practical business of flying. He knows, indeed, that winds at the surface of the earth possess very different characters in this respect, but he does not know to what extent the local situation is responsible for variation in the steadiness of the wind. On the coast winds off the sea are much steadier than winds off the shore, as well as being stronger. So much is this the case that the anemograms from a coast station are as a rule distinguishable at a glance from anemograms from an inland station like Kew, but the better the exposure of the anemometer at an inland station the steadier is the wind recorded. A better exposure means in general a greater height above the ground and steadier winds are met with as the altitude is increased. The steadier winds from the sea and at greater heights is due to the absence of obstacles like trees, houses, hills, etc., which break up the steady flow of air and cause eddies, and these eddies will travel a long way down the wind, as is proved by the following curious fact observed at Southport. At Southport the anemometers are erected about one mile from the town, at Marchside, on the bank of the Ribble, and the exposure is an excellent one as the country is flat for miles round. The station is in charge of Mr. Baxendell, and he noticed that the trace showing the direction of the wind always changed its character as the wind shifted through a certain definite point of the compass, being steady on one side, but unsteady on the other. The cause of this was sought for in vain for some time, but at last it was noticed that the critical direction coincided with the bearing of the last house on the parade on the Southport front, which house was at least a mile distant. This shows the long distance to which the effect of an obstacle may extend.

It is difficult to define the term "gustiness," because it is only a question of how long a gust lasts whether it should be called a gust or a squall. The numerical measure of the gustiness of the wind is obtained from a self-recording anemometer by taking the difference between the maximum and minimum velocity for a given time and dividing the difference by the mean velocity for the same time. In the absence of marked squalls and for a wind neither increasing nor falling this is a perfectly good measure, but obviously should a squall occur in the chosen interval the ratio may reach quite a high value. With one hour as the interval and using the pressure tube anemometer as the standard for measuring the velocity of the gusts and lulls, a ratio of ½ denotes a very steady and a ratio of 3/2 a very gusty wind.

### THE DRIFT CAUSED BY THE WIND.

Much misconception appears to exist as to the effect of a steady wind upon the steering and course of an aeroplane, and since the matter is quite simple it may be well to set it out, starting from first principles.

In what follows by a steady wind is meant a wind in which each particle of air is travelling with the same uniform velocity and in the same direction as every other particle, and in so far as the drift and course to be set are concerned, a gusty wind has exactly the same effect as a steady wind of the same mean velocity. Now as soon as an aeroplane has left the ground, save in the important matter of drift, it is quite immaterial to it in what direction and with what velocity the wind is blowing. The aeroplane shares the velocity of the wind, but in all other respects it is quite unaffected by it. The case is exactly the same as that of a man walking about on the deck of a steamer on a calm sea, he walks about in exactly the same way whether the steamer is anchored or is moving, and if he is in the saloon, out of sight of fixed objects of reference, he cannot tell in the slightest degree in which direction he is moving, neither, save by inference from the noise of the engines, can he tell the speed. The steamer itself is possibly being carried by a tidal current as well as by its own motive power, and the navigating officer, so far as his own observation goes, is in the same position with regard to the effect of the tide. But there is this very important distinction between the navigating officer of a vessel and the pilot of an aeroplane when both are out of sight of objects of reference. The officer knows beforehand very

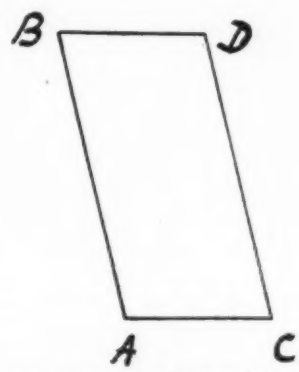
*A paper read before the Aeronautical Society of Gt. Britain, and published in the *Aeronautical Journal*.

closely what current he may expect to find at the precise time and place in which he is, but this knowledge is very imperfect for the pilot; moreover a tidal current, or a drift of the vessel through wind is in general quite small in comparison with the motion of the vessel through the water, whereas the wind which is carrying an aeroplane may have the same or even a greater speed than that of the aeroplane itself. It is this latter fact which makes the wind, even when steady, such an important element in practical aviation.

The rule by which the position is found of an aeroplane having a known velocity through the air—the velocity indicated after correction for density by the speedometer—and subject to a wind of known velocity and direction is quite simple and is best shown by a diagram.

Suppose the aeroplane to start from A and to be kept by the rudder and compass apparently heading in the direction AB. Let AB be the distance travelled through the air in a given time, say one hour. Then if it were a dead calm, after one hour the aeroplane would be at B. Suppose a pilot balloon sent up from A with its lift adjusted to float at the same height as the aeroplane, and suppose that one hour later it has moved to C. Complete the parallelogram ABDC so that D is the corner opposite A, and then D will be the position of the aeroplane after one hour.

The practical problem is, starting from a point A with the intention of flying to a point F to know what course to follow. It is necessary for the purpose to know the speed of the machine and the speed and direction of the wind. The geometrical solution is as follows:




From a map set out the direction AF and draw AC from A in the direction of the wind and of such a length that AC represents the velocity of the wind in any convenient scale. With centre C and a radius representing in the same scale the speed of the machine, describe a circle cutting AF in D. Then CD or a parallel line AB gives the course to be followed, and AF ÷ AD will give the number of time units that the flight will take.

In general the circle will cut AF in two points, the one nearest F should be taken, also it may not cut it at all, in which case the wind is too strong to render the proposed flight possible. Since AC may make any angle with AF, in the majority of cases AD will be less than CD, and therefore on the whole the wind increases the time of flight, and if the return journey is to be made under the same conditions of wind the whole time is inevitably increased.

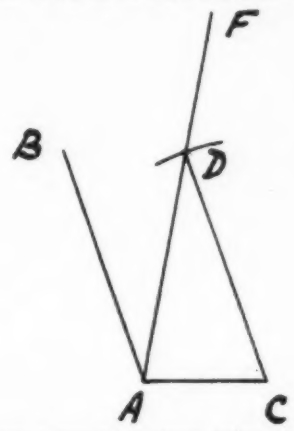
Of course, in most instances the course from one place to another is followed by a series of landmarks, but cases arise when it is not possible to see the landmarks and therefore it is of importance to know the strength and direction of the wind. This is a purely meteorological problem, and if it can be solved and if also the difficulty about steering by compass can be overcome, two ifs in both of which there is much virtue, then it will be possible to take an aeroplane from one place to another with the same certainty as there is in taking a vessel from one port to another by dead reckoning alone.

### ESTIMATE OF THE WIND.

There is no difficulty in determining the velocity and direction of the wind at the surface, but it is a knowledge of the wind at greater heights that the pilot of an aeroplane requires. The greater the height the more uncertain must any estimate become, and even at a few thousand feet the wind in most cases will differ considerably from the surface wind. The question therefore is, to what extent can we infer the conditions that prevail at, say, 3,000, 6,000 and 9,000 ft. from surface conditions that we can ascertain.

The means of observing the upper winds are observations of clouds, kites, and pilot balloons, but in all these cases, save partly with kites, the observation is confined to the space below the lowest sheet of clouds and above that sheet we have no power of observation. It is, however, just when the ground is hidden by a low cloud sheet that the knowledge is most required. Fortunately there is no reason to suppose that the connection between the surface and the upper wind is different when it is cloudy and when it is clear; in my own experience of kite flying I did not find any break in continuity at the surface of a cloud layer rather than at any other level.

If a person stands facing the wind and there are low clouds in sight he will generally find that the clouds are coming somewhat from his right, and he will also infer, and rightly so, that the wind is stronger at the cloud level than at the surface. How much stronger will depend upon the exposure of the station, but at a rough rule it may be said that over an inland station at 2,000 feet the wind will have doubled in velocity and will have veered two points. At a coast station a sea wind will have increased perhaps 50 instead of 100 per cent. At greater heights the wind will probably continue to veer and increase in strength, but nothing like to the same extent, and perhaps the best way of giving the average result is to say that with increasing altitude the westerly component will increase in strength. This is equivalent to a considerable veering at heights above 5,000 feet in south and south-east winds and to a small backing very often in north and north-west winds. All that one can infer from the surface wind is that at an elevation of a few thousand feet the wind will be roughly doubled in velocity and will have veered a few points.




For many years past, years before the war, the Metcorological Office have had inquries addressed to them from artillery officers and others as to the strength and direction of the upper wind, and their experience has led them to the belief that the most reliable estimate can be made from the distribution of the surface barometric pressure. There is not time or space to go fully into this matter and a brief statement must suffice.

If a person stands in the northern hemisphere with his back to the wind he will have the lowest barometer on his left hand, if the wind is strong then the fall of the barometer from right to left will be rapid, if light the change in barometric height will be small. This is Buys' Ballot law.

At first sight it would appear as though the wind would blow from places of high to places of low barometer, but a little consideration shows that such conditions could only be very short lived. For if air flowed into a low pressure area to any appreciable extent it would only take a time to be measured in minutes for the low pressure area to be filled up by the incoming air to be replaced by a high pressure area. Observational facts make it perfectly clear that on the average at the height of a few thousand feet the wind blows along the line of places where the pressure is equal, along the lines which on a weather chart are called isobars, lines that is of equal pressure. Also the velocity is proportional to the barometric gradient, that is to the change in the height of the barometer along a line at right angles to the isobar.

The reason for this lies in the rotation of the earth on its axis, and a comparatively simple mathematical process enables us to calculate the precise velocity of the wind that should correspond to a given barometer gradient in any place. The wind coinciding in direction with the isobar and with a velocity computed by the formula is called the "gradient wind," and if the wind be asked for in the strata commonly used by aeroplanes the best answer is to give the gradient wind. For straight isobars the formula is $y = 2\omega v \sin\phi$ where $y$ is the barometric gradient, $\omega$ the angular rotation of the earth, $v$ the velocity of the wind, and $\phi$ the latitude of the place.

It has been already stated that it is an observational fact that on the average the wind at 3,000 feet does agree with the gradient wind, but it cannot be denied that in each individual case the agreement does not appear to be precise. It seems likely, in view of recent suggestions, that on certain parts of the weather chart the agreement cannot be expected to be precise, but on the other hand, the discrepancies which appear are such that they may quite reasonably be put down to observational error. Irregularities of pressure occur which are not shown on the weather map, because they are too local to be shown by the barometric data of stations lying one hundred miles or so apart from each other, and it may well be that the gradient wind and the true wind do really agree, but that the former cannot be calculated from the chart with sufficient nicety of detail to make the precise agreement plain.

Also our means of observing the actual wind at 3,000 feet, or other heights, by means of pilot balloons are not absolutely accurate since in general they assume a uniform rate of ascent on the part of the balloon, and this is not strictly true.

However, accepting the statement that at the present time the best means of estimating the upper winds is by means of the pressure distribution and that we may take the records of pilot balloons as reliable it is of interest to ascertain what accuracy may be expected. Thus, if a pilot is in the air one hour and has been told that the wind is blowing at the rate of 20 miles an hour from the west, whereas in reality it is only ten, he should find himself ten miles west of his proper destination. Equally, if the wind's direction had been wrongfully estimated by 30° and it were really 20 miles per hour from 30° north of west (W.30°N.) he would find himself 10 miles south and about three west of his landing place. To ascertain what the usual error would be I have taken the observations on pilot balloon ascents, published by the Meteorological Office in the *Geophysical Journal* for 1915, and compared the actual wind at .5km., 1.0km. and 1.5km. (1,640, 3,281, 4,922 ft.), with the gradient wind deduced from the charts of barometric pressure. There are from 200 to 300 ascents available. In accordance with a common practice in dealing with statistics they have been divided into two groups, January to June and July to December. The results are given in Table III.

TABLE III.

| | Group. | .5km. | 1.0km. | 1.5km. |
|---|---|---|---|---|
| Probable error in miles per hour of estimated wind | I. | 4.2 | 5.0 | 5.5 (127 obsns.) |
| | II. | 4.7 | 5.5 | 5.2 (134 obsns.) |
| Probable error in degrees of direction | I. | 16° | 17° | 16° |
| | II. | 16° | 13° | 12° |
| Probable error of component perpendicular to isobar | I. | 3.4 | 4.0 | 4.0 |
| | II. | 4.4 | 5.1 | 4.1 |
| Combined probable error | I. | 5.4 | 6.4 | 6.8 |
| | II. | 6.5 | 7.5 | 6.7 |

| | Group. | .5km. | 1.0km. | 1.5km. |
|---|---|---|---|---|
| Mean excess of real wind over gradient wind | I. | .8 | 3.0 | 3.6 |
| | II. | .5 | 2.1 | 3.0 |
| Mean excess in degrees of direction of real wind over gradient wind. (Positive directions N.-E.-S.-W.) | I. | —18° | 2° | — 1° |
| | II. | — 5° | 0° | 0° |

The two groups show a good agreement save in one particular and also the number of observations is ample. It may be well to explain here the meaning of the term probable error. It is that for any one estimate the chances are equal whether the error made is greater or less than the probable error. The chances are 22 to 1 against an error exceeding three times the probable error and 142 to 1 against exceeding four times. The discrepancy in the mean angle of the real wind with the isobar, —18° for the first half year and —5° for the second, seems to be due to an excess of easterly winds in the first half as east and south-east winds often have a large incurvature.

The chief point in the table for our purpose is the magnitude of the combined error. Suppose a balloon adjusted to float at 3,000 ft. for one hour and that we wished to foretell its position at the end of the hour by means of the isobaric chart. There are two errors concerned, one in the line of the isobar owing to a wrong estimate of the velocity and one at right angles to this owing to a wrong estimate of the direction. These are probably independent and therefore the combined error is the square root of the sum of the squares. This would not be true for cases where the gradient wind is zero or very small, but such cases are not numerous enough to seriously alter the result. Thus, taking the supposed case of the balloon, and this is strictly analogous to a pilot flying without the use of landmarks, if the position be plotted by an isobaric chart and then a circle be drawn of seven miles radius with that position as centre, in about half the cases the balloon would lie within that circle at the end of the hour and in about half without.

This does not, of course, include any difficulties about the compass.

For two hours the error would be doubled, for three hours trebled, and so on, but as the length of flight increases other considerations come into play which we must consider. For a long flight the estimate of the wind to be allowed for depends upon the weather chart as it will be some hours hence and not as it is at the time, thus involving the necessity for forecasting the chart. I do not propose to enter into this point beyond saying that it must increase the error. Further, any error in the earlier part of the course of the aeroplane would bring it into an unanticipated position both in place and time in the latter part, and this again increases the probable error. These are both disadvantages. But there is another respect in which a long flight may possibly have the advantage. It may perhaps be that the discrepancies shown between the gradient wind and the wind as deduced from the ascent of a pilot balloon are merely local and temporary and that the error when integrated over a long course may very largely cancel out. Whether this is the case or not the future will show. My own opinion rather is that a probable error of from 5 to 10 miles for each hour in the drift of an aeroplane will have to be reckoned with for some time to come, though doubtless the error will decrease with time and experience.

There is the possibility of a systematic error in some of the values of Table III. The results are not published unless the pilot balloon is followed up to a height of at least 2.5 km. Other things being equal this is more likely to happen when the wind is decreasing than when it is increasing above. Since a pilot balloon under 3 km. is generally lost sight of behind a cloud rather than by getting too far away, the error so caused is perhaps small.

The table is only carried to 1.5 km., for greater heights the probable error of the drift increases, but the systematic error mentioned above will become more and more effective, and it is very doubtful if anything worthy of the name of an estimate can be made from the pressure distribution for heights over 15,000 ft.

THUNDERSTORMS.

The dangers due to thunderstorms are mentioned by Captain Cave in the paper already referred to (Vol. XXI., p. 301, of the *Aeronautical Journal*), and it is a point on which further information is much to be desired. There can be no doubt that in some thunderstorms very violent air currents occur, this is apparent from the motion of patches of cloud; from theoretical considerations also it is probable that strong ascending currents of air are to be found in some part of every storm, but in many storms no clouds that can be seen show any violent motion. There is also the danger that the aeroplane may form part of the path of a lightning flash. Most likely the great majority of flashes follow a more or less horizontal path from cloud to cloud and it seems inevitable that an aeroplane near the prospective path should carry part of the discharge. Still the risk cannot be nearly so great as in the case of a kite or captive balloon connected to the ground by a metal wire.

The ordinary thunderstorm, apart from the line squall variety, does not cover a great extent of country, neither as a rule does it travel very fast, and there is little doubt that an aeroplane could avoid it. But it would probably be dangerous to try to pass over it. The difficulty seems to me to be to recognise a thunderstorm as such.

Of all meteorological phenomena thunder is perhaps the easiest to foretell without the use of instruments, for as many of us have noticed thunder clouds have a very distinctive appearance that a good observer may learn to recognise. A really fine thunder cloud with its sharp edges and strongly defined contrasts of color is unmistakable, but such a cloud passes by many graduations into the soft harmless summer cumulus and no precise line can be drawn as to where the one ends and the other begins. Mere blackness in a bank of clouds does not denote thunder, sharpness of edge is the characteristic sign. Blackness is sometimes merely the effect of contrast and may appear in a sheet of fine weather stratus cloud when the sun is low down on the opposite side of the sky. If the upper edges of a bank of clouds are soft and fleecy it is almost certain that while that condition holds no thunder will occur. I exclude from my meaning of "soft and fleecy" the false cirrus that so often grows from the top of a cumulus, and which has an unmistakable appearance of its own. On the other hand, if the upper part has well defined sharp edges it is, in the summer at least, not improbable that thunder will follow. But while I think it possible to separate most days into two classes, those in which thunder is likely and those in which it is very improbable, I do not think it is possible to define from its appearance any cloud or bank of clouds as one in which thunder will or will not occur within the next half hour.

It is superfluous for me to repeat Captain Cave's remarks about the line squall.

## Action of Iron Oxide on Silica Bricks

ASSUMING that the pouring temperature of steel is about 1,650 deg. C., and that the best silica bricks have a melting point of 1,750 deg. C.—which is probably too high a figure—it will be understood that slight excesses of temperature in the steel furnace may do serious damage to the arches which are built up of silica bricks for want of any better material. Apart from the direct action of the heat, the local effects of the flames, the gases and particularly the dust and liquid metal from the charge and the bath, are the chief factors which endanger and modify the bricks. In a recent communication to the Paris Académie des Sciences Rengade distinguishes four zones in the bricks which have done service for some time. Proceeding from the hearth upward he designates these zones by the letters A, B, C, D, D being the unaltered portion of the bricks highest above the bath. The same number of the *Comptes Rendus*, of May 13, 1918 (pages 764 to 769) also contains a paper by H. Le Chatelier and B. Bogitch, dealing particularly with the effect of the iron and its oxides on the bricks. Le Chatelier states that his conclusions agree absolutely with those of Rengade; to us there appear to be differences sufficiently striking to question at any rate the "absolutely." The zones of Le Chatelier are: A, a gray zone in which the original silica of the brick has more or less undergone fusion and been turned into tridymite and cristobalite; a black-brown zone B, of large crystals of tridymite in a blackish-ferruginous medium; a zone C, in which whitish spots, fragments of the original brick particles, can be distinguished which have not quite recrystallised into tridymite or still show a nucleus of cristobalite. Tridymite and cristobalite, we may add, are modifications of amorphous quartz, to which different authorities assign different temperatures of transformation. Rengade, Le Chatelier proceeds, also speaks of regions of light yellow in the dark brown zone C, which Le Chatelier would distinguish as a separate fourth zone; but Rengade does not make mention of any yellow patches, nor does he refer to sulphates of which Le Chatelier finds, *e. g.*, 10.5 per cent. in the original brick, and 29.5 per cent. in zone C. They both state that much more iron oxide (4 per cent. or 6 per cent. according to Le Chatelier, up to 19.5 per cent. according to Rengade) is found in zones B and A than the 1 per cent. of the original brick. We will follow Le Chatelier in our further remarks. The grey zones directly exposed to the flames and to the ferruginous dust are less rich in basic oxides than the zones higher up, and in the brown or yellow portions lime accumulates, especially with relatively rapid fusion. The iron oxide ascends in the capillaries of the bricks; when a new brick free of iron is placed upon another rich in iron, the iron will after heating for an hour to 1,600 deg. C. have travelled upward into the new brick to a height of 5 mm., especially in a reducing atmosphere. When a pill of compressed iron oxide is placed on the top of a silica brick, which is heated to 1,200 deg. C., a hole is formed of the dimension of the pill, and ferrous silicate diffuses into the brick; in an oxidising atmosphere the pill remains intact even at 1,400 deg. C. That the basic oxides diffuse, is due to the fact that the brick, where directly exposed to the flames, contracts, loses its porosity and squeezes the ferorus slag out, forcing it into the colder portions. This shrinkage may lead to the formation either of semi-fused patches, which fall off, or completely-fused stalactites. Metallic iron, sprayed on to the bricks in drops or placed on them, gives rise to the formation of holes, protoxide and an easily-fusible slag being formed. As regards the enrichment of lime in certain zones Rengade says that the lime silicate fuses and rises in the capillaries, while Le Chatelier maintains that it is the ferrous silicate which sweeps the silico-aluminate of lime out, so that most lime is found there where the iron stopped in its rise. This he demonstrated by placing a new brick on a cushion of iron oxide at 1,600 deg. C. As a brick containing 5 per cent. of lime may have its melting-point lowered by 100 deg. C., this migration of the lime in the bricks is of great importance for the durability of the arch, and for this reason chiefly local excessive heating of ferruginous silica bricks is so injurious.—***Engineering.***

## A New Refractory and Abrasive Material Called Corindite

BAUXITE when melted by mixing it with anthracite and blowing air through the mixture (Lecesne, Fr. Pat. 471,513; this J., 1915, 356), yields a vesicular mass containing many small crystals of alumina. To this material the term "corindite" has been assigned. It has a higher melting point than the original bauxite owing to the reduction of the iron oxide to metal and spinel ($Al_2O_3FeO$) and the separation of some of the more fusible constituents. The product made from white (Var) bauxite is suitable for lining furnaces and other refractory purposes; the material made from red bauxite forms an excellent abrasive and substitute for emery or corundum.—*Note in J. Soc. Chem. Ind. on an paper by A. Bigot before the Ceramic Soc.*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